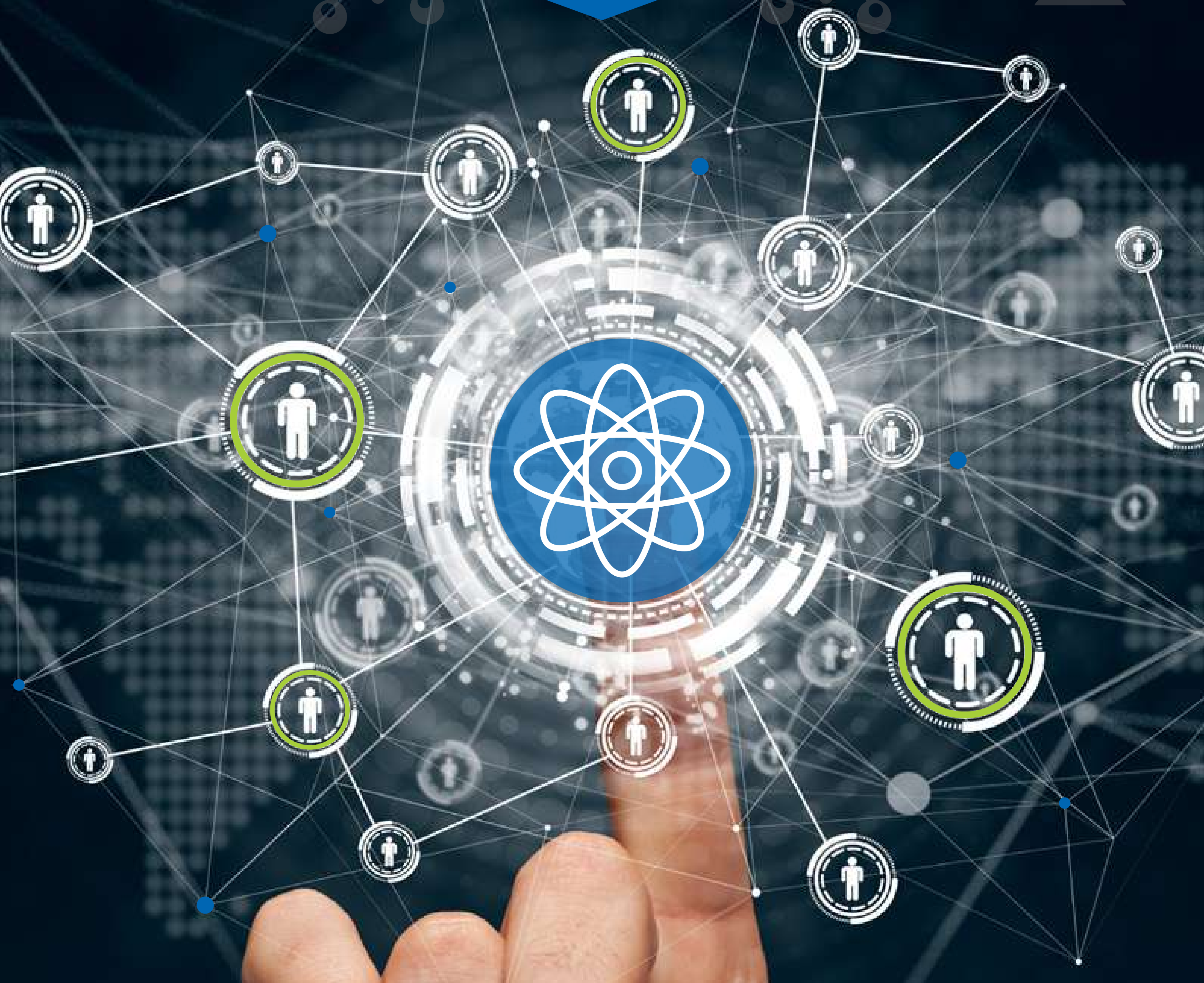
SCIENCE AND THE PUBLICS:
Mapping Public Relationship with Science Surveys

2020



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ABBREVIATIONS AND ACRONYMS

4IR Fourth Industrial Revolution
AAAS American Association for the Advancement of Science
AI Artificial Intelligence
ANC African National Congress
BIS Business, Innovation and Skills
BSA British Science Association
BSE Bovine spongiform encephalopathy (Mad Cow Disease)
CAPI Computer Assisted Personal Interview
CoPUS Committee on the Public Understanding of Science
CRISP China Research Institute for Science Popularization
DBE Department of Basic Education
DOSM Department of Statistics Malaysia
DSI Department of Science and Innovation
DST Department of Science and Technology
EPOP Evaluation of Public Opinion Programme
ESS European Social Survey
EU European Union
FRD Foundation for Research and Development
GfK Growth for Knowledge
GP Gauteng Province
HSRC Human Sciences Research Council
ICT Information and Communication Technology
IDRC International Development Research Centre
IEA International Association for the Evaluation of Educational Achievement
IK Indigenous knowledge
IKS Indigenous knowledge systems
IRP Integrated Resources Plan
ISSP International Social Survey Programme
FEST Foundation for Education, Science and Technology
HSRC Human Sciences Research Council
LoLT Language of Learning and Teaching
MASTIC Malaysian Science and Technology Information Centre
M&E Monitoring and evaluation
MEF Monitoring and Evaluation Framework
NBS National Bureau of Statistics
NCAER National Council of Applied Economic Research
NDP National Development Plan
Necsa National Energy Corporation of South Africa

NGO ...... Non-governmental organisation
NISTADS ...... National Institute of Science, Technology and Development Studies
NRF ...... National Research Foundation
NSB ...... National Science Board
NSF ...... National Science Foundation
NSI ...... National System of Innovation
OECD ...... Organisation for Economic Co-operation and Development
PAPI ...... Paper and pencil interviewing
PAS ...... Public Attitudes to Science
PISA ...... Programme for International Student Assessment
PRS ...... Public relationship with science
PUB ...... Public understanding of biotechnology
PUS ...... Public understanding of science
ROSE ...... Relevance of Science Education
R&D ...... Research and Development
S&E ...... Science and engineering
S&T ...... Science and technology
SAASTA ...... South African Agency for Science and Technology Awareness
SASAS ...... South African Social Attitudes Survey
SEIMS ...... Science Engagement Information Management System
SES ...... Science Engagement Strategy
SET ...... Science, engineering and Technology
SKA ...... Square Kilometre Array
SMME ...... Small, medium and micro-sized enterprise
STEM ...... Science, Technology, Engineering and Mathematics
STI ...... Science, technology and innovation
S&T ...... Science and Technology
TIMSS ...... Trends in International Mathematics and Science Study
UK ...... United Kingdom
USA ...... United States of America
VA ...... Vetenskap & Allmänhet
WC ...... Western Cape
WVS ...... World Values Survey

DEFINITIONS

Attitude	Degree of like or dislike for something.
Indigenous knowledge	Local knowledge that is unique to a given culture or society, and is usually passed from generation to generation by word of mouth.
Interest	A state of curiosity or concern about, or attention to, Science and Technology (S&T).
Perception	Formation of a concept such as Science and Technology (S&T) through the interpretation of what is seen and heard.
Publics	All people in society who are not involved in Science and Technology (S&T). This group includes: learners, professionals who are not experts in S&T and the lay public.
Relationship	A connection or association between the publics and Science and Technology (S&T).
Science	Incorporating Science, Technology, Engineering and Mathematics (STEM) subjects, but also focusing on knowledge more broadly (including the social sciences).
Science communication	The use of appropriate skills, media, activities and dialogue to promote awareness, interest, enjoyment, opinion-forming or understanding of science.
Science engagement	The interaction of the public and the Science and Technology (S&T) community in areas such as S&T policy formulation. Interactions are characterised by mutual learning, rather than a one-way transmission from 'experts' to publics.
Scientific awareness	The ability to perceive, or to be conscious of science events, objects or patterns, which does not necessarily imply understanding.

Scientific culture	A society-wide environment that appreciates and supports Science and Technology (S&T) and scientific literacy.
Scientific knowledge	Assimilating Science and Technology (S&T) facts and principles.
Scientific literacy	The ability to understand and communicate about Science and Technology (S&T).
Science and technology	An all-encompassing term used to refer to pure sciences, mathematics, statistics, engineering, technology and medicine.
Scientific community	Professionals who work in the Science and Technology (S&T) sector or who have tertiary qualifications in S&T.
Trust	Confidence or faith.
Understanding	A comprehension of the laws and theories that govern Science and Technology (S&T).

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EXECUTIVE SUMMARY

Background and rationale for the report

In 2008 the Human Sciences Research Council (HSRC) and the South African Agency for Science and Technology Advancement (SAASTA) collaborated in shaping a research agenda for public and science surveys, and the first task was to publish a report entitled *Science and the publics: a review of public understanding of science studies* (Reddy, Juan, Gastrow and Bantwini, 2009). The report reviewed a selection of theoretical and empirical contributions that have shaped the broad area of public and science research. The report popularised the notion of the many South African *PublicS*, highlighting the multidimensionality of society and problematising the notion of a '*general public*'. Beyond this, the 2009 document recommended that the Department of Science and Technology (DST/Department of Science and Innovation (DSI)) adopt a significant leadership role in shaping science communication directed at the public within the National System of Innovation (NSI). The recommendation was for a strategic review of communication practices, with preference being given to dialogical bi-directional public engagements rather than to former unidirectional communication practices. In the years following the 2009 Report, the critical recommendation was to enhance national science engagement policy objectives and develop relevant, reliable and high-definition data sets to support effective decision-making.

This background serves as the rationale for the 2020 report, *Science and the publics: mapping public relationship with science surveys*. The present document updates the earlier report, highlighting the theoretical, empirical and policy iterations that have directed and supported the drive to better understand effective science promotion and engagement ambitions across the research domain.

In 2020, we face a rapidly changing world full of uncertainty as it deals with the COVID-19 pandemic, the oil price crisis, the impact of climate change, global economic shifts and the ever-present threat of conflict. The present report therefore comes at a time when the public rely increasingly on science to sustain and support their daily lives, and even more heavily so in situations of hardship and inequality, where technological solutions are specifically called upon to unlock the potential of populations across the Global South. In the Global North and the more industrialised nations, technology has created massive fortunes, changed the course of disease outbreaks and influenced politics and policy in ways never previously thought possible. Science and technology are therefore what link the idea of modernity to our species.

While continuing to grapple with the impacts of apartheid policies and high rates of inequality, poverty and underemployment, South Africa has to keep pace with the technological advances which influence the role we play as civically engaged citizens and deal with their many unintended consequences. To pre-empt the far-reaching implications on South African citizens, the Department of Science and Innovation, together with its strategic partners at the Human Sciences Research Council, has been leading the process to measure and understand the particular social fingerprints of the public's relationship with science.

The aim of the present report is therefore to capture the current status of the public's relationship with science and so provide a better understanding of this particular global and South African moment. The research report thus aims to support effective forward planning and sustainable science engagements to enable the continued development of a South African citizenry functionally familiar with, and supportive and critical of both domestic scientific contributions and the impact of science on everyday lives.

How we conducted this study

This 2020 state-of-the-art scoping exercise reviews the literature and multi-country surveys for the purpose of establishing the rationale and recommendations for a future public and science survey. The report includes empirical work (published predominantly in English) from around the world and conducted between 1979 and 2019, including surveys executed in South Africa from 1990. International work is drawn geographically from approximately 20 countries including the United States, European member states, China, India, Sweden, and Malaysia. South African studies include the seminal work of the precursor to the SAASTA, the Foundation for Education, Science and Technology (FEST), as well as the work of the HSRC (including the South African Social Attitudes Survey). Within the South African context specifically, the policy instruments which have influenced the public and science debates in the South African National System of Innovation are examined. The report adopts a holistic approach, in scope and definition, when mapping the South African public's relationship with science. This 2020 version contains an abridged history of the development of policy instruments and, in capturing the process of policy evolution in South Africa, reviews the literature. Mapping the history of both policy and practice, domestically and within selected geographical regions, the report offers a lens through which to view the global public-science interaction space. It also aims to strengthen the foundation from which to accelerate enhanced science promotion and engagement practices among the South African population.

Key findings from our review

The report picks up where the previous one ended and therefore represents continuity in mapping out the development of this space within the South African context. The literature and empirical data reviewed and summarised in the following pages support the set of key findings and recommendations at the end of this report.

Within the context of advancing strategic policy directions in South Africa, the DSI, through its science promotion directorate, has initiated a programme of work related to public engagement with science. The report finds that, within the global community of practice, the progression towards a bi-directional-engagement and science-promotion approach supports the ideals embedded into the DSI's *Science Engagement Strategy*. The four strategic aims are (1) to popularise science as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers; (2*)* to develop a critical public that actively engages with and participates in the national science and technology discourse to the benefit of society; (3) to promote science communication that enhances science engagement in South Africa; and (4) to profile South African science and scientific achievements domestically and internationally, demonstrating their contribution to national development and global science, thereby enhancing their public standing. The policy framework identified a series of enablers and interventions within each strategic aim, which are discussed in detail in the SES Implementation Plan (2017). The 2019 White Paper on Science, Technology and Innovation, advocating for a 'science-literate and science aware society', articulates a renewed focus on building the science–society linkages through effective communication, capability building, adequate funding and citizen engagement. Further, the policy document, among other data gathering and knowledge mobilising activities, recommends the establishment of a 'set of indicators to measure the success of system-wide science engagement…which will inform an institutionalised survey on public perceptions of science and country comparison studies'.

International empirical practice highlights the importance of attitudinal variables, demonstrating the global trend in informing domestic and international science policy-making initiatives. The uniqueness of the South African population, reflected in its diversity, benefits from this widened scope and focus of research into the science–public relationship. Moreover, it opens the space to an enhanced and evidence-based two-way dialogue, thus bringing the public to the fore within science policy planning and intervention development.

The study of the *public understanding of science* and *science literacy* has evolved over the last 60 years, globally and in South African society. Following the detailed reviews and findings from within the literature and policy context, the HSRC team puts forward eight recommendations for the community of practice and the future of science engagement in this country. The DSI, through its strategic collaborations with the HSRC and other NSI stakeholders, will conduct a public attitudes survey every five years, and the survey must be complemented by other qualitative and social listening methodologies to tap into the uniqueness of the South African *science culture*. However, given the uniqueness of this culture, care has to be taken when developing research instruments to ensure that the general importation of methodologies and practices does not influence the data collected within the domestic population. Detailed psychometric and other related and relevant testing methodologies have therefore been identified as critical to the formulation of the research instruments. The multidisciplinary nature of the public–science interface manifests in a variety of research contributions, from machine learning and artificial intelligence to attitude-formation and the psychological antecedents of science engagement behaviours. The social and infrastructural capacity of the NSI further supports an enhanced domestic science culture. This must leverage support from business, civil society and other public actors to ensure the deeper social and intellectual impact of the science engagement work programme.

A clearer understanding of the drivers of public attitudes and patterns of information assimilation will significantly bolster our ambitions to achieve more effective information dissemination and communication strategies. Similarly, understanding the essential dynamics of knowledge production ecosystems in South Africa feeds into these strategic approaches to creating and enabling an engagement-focused space for dialogue between members of the scientific community and the public. The public are increasingly an equal and valued partner in setting the agenda for the future of science globally. Harnessing the influence of science and technology (S&T) in driving the ambitions of South Africa, economically, socially and democratically, requires an active and engaged citizenry which is, in turn, highly dependent on an enhanced public relationship with science.

1. REVIEW UPDATE AND THE SOUTH AFRICAN PUBLICS

1.1 Introduction

In 2008, the *South African Agency for Science and Technology Advancement (SAASTA)* and the Human Sciences Research Council (HSRC) collaborated on shaping a research agenda related to public and science surveys in South Africa.[1] The first step in shaping the agenda was to conduct a scoping exercise by reviewing the Public and Science field, both internationally and in South Africa. The review culminated in the report, *Science and the publics: a review of public understanding of science studies* (Reddy, Juan, Gastrow and Bantwini, 2009).[2]

The starting point for our Public and Science Survey Review was that South Africa is a highly diverse country with a diverse population, hence there are many *publics*. The research in past surveys has provided information related to a single public. In order to interpret the meaning of the measurement statistics it is important to provide a comprehensive description of the diversity that exists i.e. the different publics. We recognised that a single 'national' statistic in a highly stratified society like South Africa could be misleading, and that disaggregated statistics by particular demographic groupings would provide a more nuanced and meaningful description for the different publics.

In the Review, rather than only measuring the views of the public towards science and technology, we also explored the role different communication channels played in shaping the views of the public. The views of the public are shaped by the types of engagements members of the public are involved in and the types of messages they receive – from their families, at school, at college or university, at work, and less formally through reading and leisure activities. These interactions allow an individual to acquire knowledge that will allow them to construct an image of science and technology and form opinions about these topics.

Knowledge, values and attitudes vary among individuals and within groups, and in unequal societies these aspects are influenced by the social role that individuals or groups occupy. The views towards science and technology are influenced by the existing science culture, which varies among different demographic, social and cultural groups.

The public are not passive recipients of general or science and technology information. They engage with information and provide feedback to knowledge producers, thus shaping the science and technology agenda in the country. Therefore we located the study within a framework that recognised that there was a dialogical (bi-directional) relationship between the public and science and technology; a relationship within which both shape and are shaped by each other. We termed the framework for the study the *Public Relationship with Science*.

The 2009 Report outlined the theoretical, political and methodological debates informing the public's relationship with science and technology. We documented the public understanding of science surveys appearing in English language publications and reviewed them for their theoretical positioning, and methodology used, including the sample and mode of data collection as well as the findings emerging from the study. We concluded with recommendations for how South Africa could move forward with a research agenda relating to the public's relationship with science. The word *relationship* encompasses the notion of two sides: on the one hand are the reception and interpretation of scientific information through varying

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1 In 2008, Beverley Damonse (SAASTA) and Vijay Reddy (HSRC) attended a Science Culture Indicators workshop at the National Institute of Science, Technology and Development Studies (NISTADS), New Delhi, India. The focus of the workshop was to plan for a multi-country Public Understanding of Science Survey. They presented a paper entitled *Cross-national comparative studies: learnings from South Africa's participation in TIMSS.*

2 Available at http://repository.hsrc.ac.za/handle/20.500.11910/4714.

media channels and information sources, mediated by evolving public attitudes, values and knowledge; and on the other hand is the scientific community, facing the public and understating the drivers and motivators of effective engagement as well as the culture of science that permeates all science communication and engagement activities. It is the nature, impact and various stimuli as prerequisites within this public–science interface that attract significant attention within our particular research approach. This view was reinforced in the Department of Science and Technology's[3] Ten Year Innovation Plan for South Africa which indicated that 'as South Africa strives to become an innovative society, it is essential to support the public understanding and engagement with science' (Department of Science and Technology, 2008).

1.2 Key Recommendations from the 2009 Study

In 2009, against the backdrop of South African policy relating to the public and science, we reviewed the international and local public understanding of science surveys as well as emerging theoretical debates to make the following recommendations.

1. In the formulation of a *public and science research agenda*, it is important to remain cognisant of the bi-directional relationship between science and society. Science engagement is the dominant discourse and framework, and the need for two-way interactions has been highlighted. Other aspects that are important in this relationship are:
    i. the diverse nature of societies and the notion of multiple publics;
    ii. the attitudes, values, knowledge, interest and behaviours of the public to Science and Technology (S&T);
    iii. the contribution of indigenous knowledge systems (IKS);
    iv. the importance of communication and appropriate messaging, including the influence of social media and technology on the public understanding of science (PUS) and awareness programmes;
    v. citizen research as bi-directional learning opportunities; and
    vi. the creation of science engagement platforms.

This framework considers both science and the public as important stakeholders in the relationship, and acknowledges that each affects the other, rather than previous frameworks where science occupied a position of power and perceived the public to be more or less deficient. Our approach encourages greater engagement between science and the public, opening up more effective dialogue spaces for mutual learning and social development opportunities.

This framing is in keeping with the (then) Department of Science and Technology's Ten Year Innovation Plan for South Africa, which indicates that 'government's starting point is that the members of the public are not merely passive recipients of science and technology, but are important players in processes that shape the focus and patterns of science, technology and development' (Department of Science and Technology, 2008).

2. The agenda of the public's relationship with science should be *driven by government with the relevant public and private stakeholders as critical partners*. It would be appropriate for the Department of Science and Technology to champion this public relationship with the science agenda and provide the appropriate resources to ensure that effective communication strategies are set in place.

3 In 2019, the Department of Science and Technology was renamed the Department of Science and Innovation. In this report the Department of Science and Innovation (DSI) will be used. DST is used for referencing purposes only for documents that were produced before the Department was renamed, or when presenting recommendations from the 2009 report.

3. Given the *importance of science communication* in shaping the relationship between science and the public, there should be a review (similar to this) of the theoretical tools for understanding the impact of (science) communication on attitudes towards science and technology. The decision to use a bi-directional model of the public relationship with science (PRS) leads to a need to review the conceptual and theoretical tools that could help us understand how messages and communication impact on attitudes towards science and technology. The current conceptual framework is focused on how attitudes can be measured and understood to inform policy; this needs to be extended to the other side of the bi-directional relationship to help us understand how science communication (including that instigated by policy) in turn influences these attitudes. These methodologies may be drawn from an array of disciplines. Firstly, there may be relevant literature in the existing field of PRS research or within the domain of science policy studies. Media Studies would be another primary candidate, since that discipline has a history of analysing the effects of communication and messages upon attitudes. A review will be conducted in which these (potential) conceptual and theoretical tools are assessed. Such an exercise would establish a conceptual and theoretical framework to guide this aspect of the methodology, and more broadly the aspect of the project that seeks to understand *how* policy and science communication might be able to influence or shape public attitudes.

4. We (South Africa) must plan to undertake dedicated studies on the publicS relationship with science. These studies will collect baseline information for a set of appropriate indicators. We will therefore plan to conduct these studies on a periodic basis to assess the public's relationship with science as well as undertake research that informs us how to strengthen this relationship. In studying the public's relationship with science we propose the following sub-studies:
   - A survey of the general post-school public assessing their understandings and engagements with science and technology;
   - A survey conducted in schools, and administered to both students and teachers;
   - Surveys on specialised topics such as nanotechnology, climate change, sustainable development etc., administered to selected parts of the population;
   - An analysis of science communication strategies and their impact on the publics; and
   - Qualitative studies focussing on how to enhance science communication strategies.

1.3 Why an Updated Science and Publics Review?

The 2009 Public and Science Report states: 'South Africa is in an ongoing process of economic, political and social transformation. Economically, the government is seeking to lead the economy from a resource-based to a knowledge-based economy. Politically, the strengthening of democracy is a key ambition for South Africa. This includes higher levels of civic participation in governance, entrenching the culture of democracy, and improved service delivery and accountability. A positive relationship between the public and S&T can support economic and social development as well as assist in consolidating democracy and citizenship.' (Reddy et al., 2009: 15)

Further, '(s)cience and technology are constantly shaping the everyday lives of individuals, whether in the fields of health, communication, education, governance, or consumer products. In fact it is difficult to imagine any area of our lives that remains untouched by science and technology. When these changes are aggregated at the national and international levels, S&T, innovation, and knowledge production become forces that drive economic growth and competitiveness and hold the potential for an improved quality of life' (Reddy et al., 2009: 10).

These sentiments are even more valid today. There has been a further surge towards a knowledge economy. Information and data provide key inputs into decision-making as major technological advancements, including the fourth industrial revolution, affect many aspects of our lives in the context of contemporary issues, such as the increasing awareness of climate change, awareness of the state of our environment, and the threats facing it. In 2020, health and well-being remain integral parts of our lives, and hence information about medical issues such as diseases (e.g. Ebola, coronavirus, HIV/Aids) becomes critical.

The world is flooded with information (both real and fake). Connectivity through mobile phones and social media adds to the diversity of information channels that the public are exposed to. Individuals need to cope with the avalanche of information and be able to discern the validity of the information they receive, as well as have the knowledge to understand how they could use it. In the public sphere there is growing activism relating to social issues; strong opinions are expressed; and social influencers shape the direction of debates through various digital platforms. The public are no longer passive receivers of information for consumption – rather they engage with information and engage with knowledge producers. Thus there has thus been a paradigm shift from science communication (one-way) to science engagement (bi-directional).

The theoretical debates with regard to the publics' relationship with science have evolved since our 2009 review. This review provides an update on these (see Chapter Three). From a South African policy perspective the Department of Science and Innovation (previously the Department of Science and Technology) have also evolved in their policy stances, with the introduction of a Science Engagement Strategy (see Chapter Two). In addition, the White Paper on Science, Technology and Innovation (2019) promises that a comprehensive public understanding of science survey will be conducted in South Africa. In order to prepare for that survey we needed an updated review of the policy context, literature, and methodologies surrounding public and science surveys. The authors have re-examined the recommendations made in 2009 and with their added understanding of the field have revised their recommendations for understanding the public's relationship with science in 2020.

1.4 The South African Publics in 2020

In 2019, South Africa had a total population of 58.8 million with 51.2% being female, with the population group categorisation of 81% Black African, 8.8% Coloured, 2.6% Indian/Asian and 7.9% White (StatsSA, 2019a).

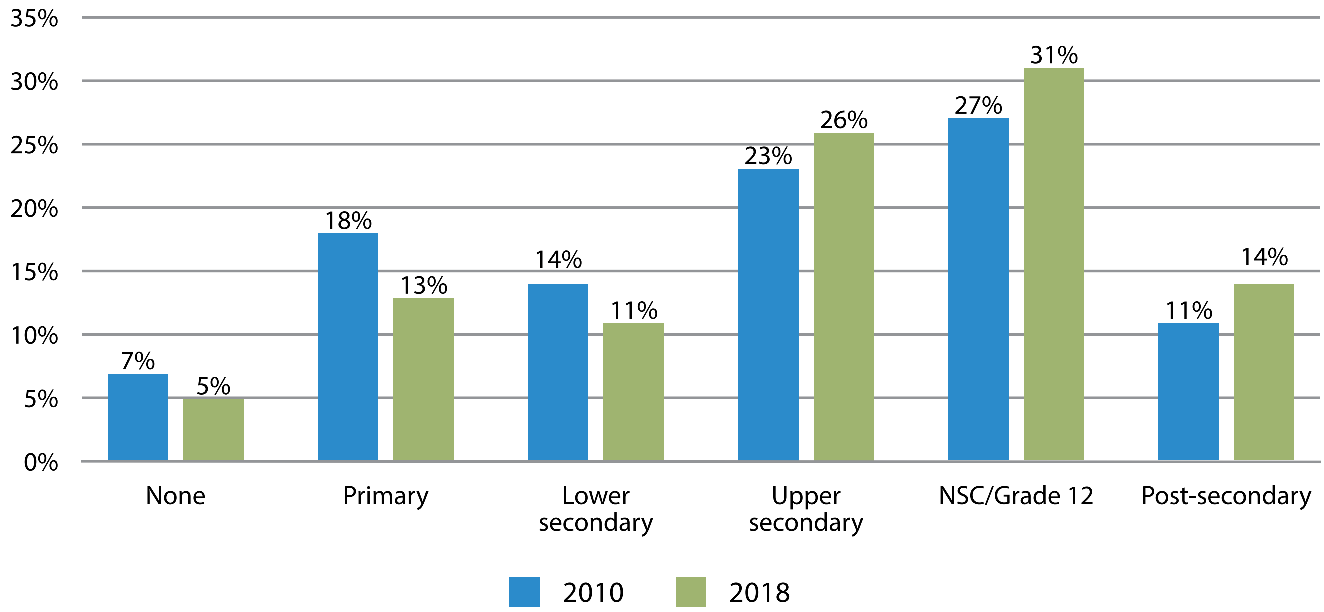
Another indicator of the diversity in the country is that South Africa has eleven official languages: isiZulu (25,3% of the population speak isiZulu at home), isiXhosa (14,8%), Afrikaans (12.2%), Sepedi (10,1%), Setswana (9,1%), English (8.1%), Sesotho (7,9%), Xitsonga (3,6%), SiSwati (2.8%), Tshivenda (2.5%), and isiNdebele (1.6%) (Stats SA, 2019a).

The most common religious beliefs in the country are Christianity (79%), followed by Traditional African religion (4,5%), Islam (1,6%) and Hinduism (1%). Smaller proportions of the population follow Judaism, Buddhism, and Bahaism. There are some who are atheist or agnostic. Religious beliefs influence the attitudes a person has towards the role of science, and it is therefore important to recognise the religious diversity that exists (Stats SA, 2016).

South Africa's diverse public is further characterised by various identifiable differences based on education, employment and income. These stratifications are the result of large inequalities between the country's rich and poor, with South Africa having the highest Gini coefficient in the world: 0.63 in 2015 (World Bank, 2019). The South African 'food poverty line' was defined as R561 per person per month in 2019. This poverty line refers to the amount of money that an individual requires to be able to afford their minimum required daily energy intake (StatsSA, 2019b). According to the most recent General Household Survey, approximately 28% of the population are classified as poor, with a monthly expenditure of less than R2 500 a month (StatsSA, 2019a). At the other end of the spectrum, 10% of South Africans own 90–95% of all wealth in the country (SAHRC, 2019). Poverty and economic inequality continue to prejudice vulnerable individuals and groups based on their geographic location, race, gender, and disability status.

Research shows that the level of education attained is one of the predictors of views about science and technology. The apartheid government provided low quality education to 'Black'[4] people, especially Black Africans. Since 1994, a number of policies have been introduced to improve the levels of education within the population, and to provide a more just distribution of educational opportunities. Figure 1 illustrates the levels of educational attainment in South Africa in 2018, as well as the improvements in education levels of individuals aged 20 years and older since 2010. In 2018, just less than half the population (45%) aged 20 years and older had completed a secondary education.

Figure 1: Educational Attainment for Individuals Aged 20 Years and Older (2010, 2018)



Source: Stats SA (2018)

The quality and outcomes of schooling, especially mathematics, continue to be low and unequal (Reddy et al., 2016). South Africa aspires to be a knowledge-based and high-skilled economy, which is dependent on a high-quality basic education system. Though improving, the pace of improvements in educational outcomes is not fast enough to meet the needs of society and the economy. For example, in 2018 there were 172 000 students who passed the matriculation examination with a Bachelor's pass (a minimum requirement for access to university and tertiary institutions), and only 51 000 (i.e. 22% of those who wrote the mathematics examination) students achieved a mark higher than 50% for mathematics – thus there was a very small pool of students who were eligible to register for high-skilled qualifications, and subsequently work in these occupations.

The universities host 1 million students, and close to 29% register for science, engineering and technology (SET) qualifications. In 2017, there were 211 000 university completers and in the SET field, 310 000

4 The term black refers to the population groups that were discriminated against during the apartheid period and refers to the Black African, Indian/Asian and Coloured population groups.

enrolments and 61 600 completers. These figures highlight the insufficient number of skilled people to respond to the labour market demands and societal challenges of the country.

South Africa continues to face a range of development challenges. Although there have been improvements in access to basic services, there are households who still lack access to these basic amenities: almost 15% of households are still not connected to the electricity grid; 11% still do not have access to running tap water in their dwellings; and 17% do not have access to sanitation in their homes. In some provinces, high percentages of households still had pit latrines in 2018, for example, Limpopo (70%), Mpumalanga (51%), Eastern Cape (48%), North West (47%), and KwaZulu-Natal (46%) (Stats SA, 2018).

There is also a digital divide in the country, with just over one-tenth (10.4%) of households having access to the Internet at home (excluding connectivity through mobile phones). Seventeen point three per cent (17.3%) of these are households in urban areas and 1.7% are located in rural areas (StatsSA, 2019a).

1.5 The Structure of the Report

Chapter two of the report outlines the key policy shifts that have evolved in relation to science communication and engagement in South Africa. Chapter three presents a review of the theoretical debates related to the public relationship with science, and the shifts that have occurred in this domain over time. Chapter four presents a comprehensive list of international surveys which have been conducted, between 1979 and 2019, and Chapter five focuses on public attitudes surveys conducted in South Africa between 1990 and 2019. In the final chapter, with the new Public Relationship with Science Survey in mind, we discuss the key findings and recommendations.

2. THE SOUTH AFRICAN PUBLIC SCIENCE AND POLICY CONTEXT

2.1 The Evolving Science Policy Context

The domestic science and technology sector has a long record, dating back many centuries in the history of South Africa. Indeed technological, social and industrial developments have kept pace and, some may argue, been mutually dependent since at least the early 1800s (Mouton and Geevers, 2009). In a country like South Africa with its complex past, the history of science policy can be divided according to multiple transition points, with the watershed moment being the first democratic elections in 1994. The rationale for this division rests on the notion that public policy should serve the citizenry of a country and that, prior to 1994, apartheid policies ensured that the scientific domain served a small minority of the South African population. Following the first democratic elections, the science system and, in fact, much of science policy were transformed to serve the majority of the population not only in terms of technological progression but also in harnessing some of the downstream impacts on society related to education, employment and economic development.

Prior to 1994, the impact of the policy of separate development, initially under colonial rule and later under apartheid, had little influence on contemporary science policy in South Africa. However, it is precisely the glaring inequalities in policy, investment, education and infrastructure as a result of the underdevelopment during the apartheid years that science policy has to correct, as we move into the twenty-first century, by using science to mobilise poverty reduction measures within the context of innovation for inclusive development. That being said, the early years of South African science did see the development of significant infrastructure, and many of the contemporary institutions of science date back to those times. The early history of the South African science system can be divided into three major periods: Colonial Era Science (pre-1916); the War Years (1916–1948) and Apartheid Era Science (1948–1994).[5] Much of the early policy and institutional development has been captured and will not be directly explored within this chapter.

The watershed moment in South African science policy began to emerge in the early 1990s. Following the release of Nelson Mandela, the African National Congress (ANC) gathered significant public support and initiated selected studies on the South African economy and policy domain. Supported by the Canadian International Development Research Centre (IDRC), a review of the South African S&T system was conducted in 1992/93. The study identified three major findings, which were that the existing S&T system in the country: (a) was fragmented and uncoordinated; (b) did not serve the interests of all South Africans; and (c) was not effective and efficient. When the ANC Government came to power in 1994, they took these findings as a point of departure and catapulted discussions on the future of science policy in South Africa into centre stage. To facilitate the functioning of the science and technology system, it was widely accepted that Government had primary responsibility for creating an enabling a policy environment in terms of regulatory and funding mechanisms to support a growing National System of Innovation (NSI) (Kahn, 2013).

The Green Paper on Science and Technology represented an early policy milestone by the (then) Department of Arts, Culture, Science and Technology. The paper highlighted two parallel challenges facing the new Government, namely, to develop a democratic mindfulness within the science system and to ensure that the NSI is sufficiently competitive to meet its objectives, domestically and globally. This was followed by the overarching policy document within the South African NSI space, the White Paper on Science and Technology

5 Categories adapted from Mouton and Geevers (2009) and Scerri (2009).

(DACST, 1996). This policy document committed to: (a) create a new policy framework for public science; (b) conduct a system-wide review of the national system of innovation in order to establish its strengths and weaknesses and future priorities; and (c) create new structures to develop, implement and monitor the new policy framework (DACST, 1996). The White Paper recognised the critical shortage of skilled human resources and the urgent need to redress the skewed face of the scientific workforce. Recognising the limitations of the Government purse, the private sector was encouraged, through the proposal of a number of funding and support initiatives, to increase productivity through the adoption of an innovation-led growth strategy. The 1996 White Paper operated in the foreground to the Growth and Development Strategy and other policy documents related to health, education, employment and economic development. As such the purpose of the White Paper could be constructed as one that was to build an enabling ecosystem for the support of the pillars of the Growth and Development Strategy.

The policy sphere until that point had focused on institutions, funding and research infrastructure, with very little attention focused on public interactions with science. The 1996 document aimed to harness S&T toward creating employment, enhancing the quality of life of citizens, developing a pool of skilled human resources and ensuring environmental sustainability, also alluding to the promotion of an information society. For the first time the importance of the public in our national system of innovation was highlighted. The White Paper expressly recognised the democratic importance of addressing significant educational and developmental disparities within the population, and critical success factors for a productive NSI. In 1996, in order to achieve these ambitions, the critical gaps in educational achievement, employment opportunities, meaningful service delivery and access to basic services needed to be improved. Active civic participation and access to information was promoted as a sine qua non within this policy space. Having a *functional* awareness of science and technology developments was essential in developing a citizenry capable of productively transforming knowledge into innovative and employment-generating activities. Beyond the dire need to enhance national rates of general literacy, the particular direction of the 1996 policy document emphasised the importance of a citizen base demonstrating a valuable degree of scientific literacy. Laugksch (1996) names three social and personal benefits arising from the development of scientific literacy, namely, economic benefit, decision-making capabilities as citizens, and the consumer, democratic and social benefits of being more active and critical citizens. However, access to technology services and a suitably skilled citizenry had become significant hurdles to realising the tremendous potential within S&T for social, democratic and economic development. The 1996 White Paper (cf. Chapter 9: Public Awareness of S&T) pointed to this as a significant challenge, but one that is critical to national policy which aims to build a more inclusive, democratic and economically active society. The document notes in particular the amplified oppression among women and those in rural South Africa, as developmental inequality is far greater outside of urban centres. The thrust of the policy intent around developing a greater public awareness of science was two-fold. Firstly, it aimed to improve literacy and thereby scientific literacy. Naturally, that included programmes to increase access to those services and technologies which supported the drive to increase the competency of all South Africans in the adoption of technology. Secondly, the policy aimed to popularise scientific activities, S&T solutions and the value of careers in science among all South Africans. The significant challenges facing South Africa at the time, in terms of infrastructure, education, employment and social protection were recognised. A number of these issues were approached through related and complementary policies falling outside the realm of the DSI. It was effectively the collaborative approach of calling on multi-stakeholder collectives to contribute and address pressing social challenges that amplified the contribution of the 1996 document to the development of early democratic South Africa.

The years following 1996 saw a number of additions to the science policy space. Although not all of these relate directly to the science engagement arena, they have all, indirectly, fed into the manner in which the public has perceived or valued the contribution of science to daily life. The National Research and Technology Foresight (1999) document responded to the notion that manufacturing industries, service sectors and knowledge institutions operated within a fast-paced and highly competitive technological environment. The policy sought to enhance competitiveness through the adoption of technology to accelerate the development of the scientific community (DACST, 1999). The South African National Research and Development Strategy (2002) identified key areas of improvement in South Africa's S&T system, and highlighted avenues to ensure productivity, employment and knowledge generation. Sector specific strategies such as the National Biotechnology Strategy (2001), as well as the National Nanotechnology Strategy (2005) similarly advanced opportunities and opened spaces for the development of high-tech nodes within the NSI.

In 2008, the (then) Department of Science and Technology introduced a guiding policy named the Ten-Year Innovation Plan (2008–2018). The plan articulates a national path of innovation, building the NSI and supporting South Africa's transformation towards a knowledge-based economy. This policy envisioned science as having a driving role in enhancing productivity, economic growth and socio-economic development through human capital development, knowledge generation and exploitation to influence the socio-economic outcomes for all citizens (DST, 2008). The policy rested on four critical pillars: Innovation, Infrastructure, Information Technology and Education. Critically the last of these relates to a human element as technology and development are highly dependent on the development of a citizenry appropriately skilled to take advantage of opportunities presented by S&T investment and output. The National Development Plan (2012) unpacks the goals South Africa has to achieve by the year 2030, identifying 14 key areas for priority focus – including education, health, safety and security, economic growth and employment – to name a few. The NDP further recognises that science and technology continue to revolutionise the way goods and services are produced, as well as the impact this may have on economic, social and developmental ambitions of South Africa.

Within the context of an evolving social, political and technological landscape, South African society, in 2014, had seen 20 years of democracy. The Department of Science and Innovarion, while recognising this in both the 1996 White Paper and the 2008 Ten Year Innovation Plan developed a Science Engagement Strategy (SES) in 2015. The SES related to the strategic direction to enhance education and basic literacy, while ensuring growth in the level of scientific literacy among the citizenry. Over and above the concept of scientific literacy, the DSI recognised the value of citizen engagement and as such adopted the notion of public engagement of science and technology within a *science in society* framework.

The SES has communicated four strategic aims, within its framework, for the enhancement of public engagement with science in South Africa. The term 'science' within the SES adopts a broad notion of modern western science, traditional as well as indigenous knowledge systems to ensure inclusivity and increase the value of broader public engagement. The critical focus within this policy document relates to developing a more informed public. Beyond the knowledge-sharing imperative, the document aims to ensure the development of a critical public – creating a more aware and civically engaged citizen base in South Africa. The four strategic aims are outlined on the next page.

- ***Strategic Aim 1:*** To popularise science as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers.
- ***Strategic Aim 2:*** To develop a critical public that actively engages with and participates in the national science and technology discourse to the benefit of society.
- ***Strategic Aim 3:*** To promote science communication that enhances science engagement in South Africa.
- ***Strategic Aim 4:*** To profile South African science and scientific achievements domestically and internationally, demonstrating their contribution to national development and global science and thereby enhancing their public standing.

Each of these strategic aims deal with specific aspects of the public-science interaction space as well as with the ideals embedded within the White Paper (1996). The focus on the accessibility of science to ensure effective career development, employment creation and economic mobility remains clear within strategic aim one. Aim two engages with the notion of the development of a critical public, issues of life-long learning as well as societal benefits emanating from the various scientific enterprises. Aims three and four deal with matters relating to science promotion capabilities (media and communication), as well as the public image of South African science domestically and internationally. A clear focus within the SES deals with the coordination of science engagement within the NSI. The DSI positions itself centrally within this area, while ensuring the role of SAASTA and the National Research Foundation (NRF) as critical stakeholders within these promotion, funding and communication processes. Further to these activities, regularised monitoring and evaluation of the system-wide impact of the science engagement programme is to be undertaken as a significant aspect of the SES's strategic direction. The development of critical engagement capabilities among the general public and the popularisation of science as viable and attractive career options have been defined not only as salient aspects of the SES but also in cross-departmental and policy-development spaces.[6] Science engagement and communication are an important element of the SES, which identifies media partners as key stakeholders. The South African media sector employs a shrinking number of professional science journalists. However, the increasing professionalisation of professional science journalism is being strongly promoted as a viable and attractive career prospect. The community of online based science contributors has increased together with the expansion in broadband and fibre coverage in South Africa – reaffirming the link between S&T, innovation and knowledge mobilisation.

The policy framework identified a series of enablers and interventions within each strategic aim, which are discussed in detail within the SES Implementation Plan (2017). Moreover, strategic sectors and institutions are identified within the document, aimed at enhancing the implementation of selected interventions and ensuring the long-term social value of the SES. The SES Implementation Plan (2017) highlights important areas for the broader implementation of the SES within society. The document aims to encourage participation in science, develop a more critically engaged citizenry, adopting science communication as a key enabler of science engagement as well as creating opportunities for the public to recognise the value of science. The implementation plan does, however, note some key enablers of the successful implementation of the SES. These include an enabling legislative environment, improved science engagement infrastructure, enhanced

6 Such as the Department of Education and the Department of Health.

capacity at SAASTA, improved grant management processes and a stable funding model for continued science engagement activities across the National System of Innovation.

The implementation plan introduces 11 non-exclusive audiences that have been identified in South Africa. These include learners, educators, students, science interpreters, journalists, industry, researchers, policy makers, tourists, indigenous knowledge communities and the *general public*. Each of the identified projects and activities within the implementation strategy relates to the spheres of influence and activity of these 11 audiences and their specific proximal or distal engagement with scientific activities. Multiple levels of monitoring and evaluation (M&E) activities are highlighted – including programme level and system level M&E. In March 2018, the SES Monitoring and Evaluation Framework (MEF) was developed. Within this process a *theory of change* and associated logical frameworks (log frames) were developed as a means to identify performance measures within the SES implementation and M&E strategy. The MEF provides a guiding document for the collection and coordination of these performance measures as well as defining the mandate of the M&E framework toward the development of the Science Engagement Information Management System (SEIMS). The MEF identified five types of evaluations that needed to be adopted for the implementation of each evaluation with corresponding timeframes. In this regard, a regularised evaluation cycle will need to be initiated in accordance with the requirements of the SES and the MEF guidelines.

The Department of Science and Innovation has since produced an update to the 1996 White Paper recognising that STI alone cannot address all of the development challenges facing South Africa. The policy also acknowledges that the significant national investment in the NSI has not translated into substantial advances in innovation performance over the past two decades. It recognises that South Africa's STI policy needs renewal to address several factors that have stalled progress. The 2019 White Paper on Science, Technology and Innovation adopts a more inclusive look at the role of Government, the public and science, than the 1996 document recognised. The approach to the concept of innovation is more wide-reaching and inclusive, embracing both the public and private sectors while simultaneously aiming to instil an understanding and appreciation of innovation in a government-wide manner. This promotes the inclusion of innovation activities and reporting in all planning and budgeting practices within and across government. The new document aims to integrate all sectors of the economy within an innovation-rich environment.

The creation of a more enabling innovation environment remains a critical aspect of the 2019 White Paper – wherein SMME and emerging business benefit through the promotion and development of support programmes and incentive schemes. With the advent of the *Fourth Industrial Revolution* and the dramatic impact of climate-change-related events, emerging sectors for promoting research and economic activity could be capitalised. Human capability development is of increasing importance –education, training and development programmes, especially, to redress gender and race imbalances and develop the STEM capabilities of the future S&T human workforce in South Africa. These critical skills will be directed to key priority areas such as indigenous knowledge, trans-disciplinary areas as well as the emerging areas of research and development. A critical aspect of the 2019 White Paper remains identifying more suitable and diversified funding models for science institutions and government-supported research initiatives. The private sector has been encouraged to advance business-led innovative activities in South Africa, while government is focusing its resources on tertiary and science-council investments directed at applied research which target critical social priority areas. The important shift from the 1996 White Paper to the 2019 White Paper was the change in focus from the development of the early National System of Innovation (in the former) to a renewed focus on building the science-society linkages through effective communication, capability building, adequate funding and citizen engagement. This changing focus relies extensively on civic partnerships – between government, civic society, higher education, foreign partners and business.

The revised White Paper sets out an ambitious agenda for the future of science in South Africa, aimed at developing a more pervasive and inclusive notion of innovation across society and harnessing the value S&T may deliver in achieving the goals within the National Development Plan.

The 2019 White Paper shifts the focus toward a more *science in society* approach, acknowledging simultaneously the significant infrastructural, social and economic advances as well as the many momentous challenges that still lie ahead in South Africa. The major information and communication technology (ICT) revolution, which has transformed the way society produces, shares and values information – has created a society that has become integrated within technology developments. Since the 2008 Ten Year Innovation Plan (DST, 2008), the Department of Science and Innovation has recognised the latent potential within technology spaces which could benefit South African society and development. Active participation in global platforms on political, cultural, educational and economic areas remains a strategic focus of the DSI in the 2019 White Paper aimed at unlocking this latent potential in S&T areas. As a result of economic and social inclusion, strategic partnerships, better cross-departmental coordination, enhanced stakeholder consultation, system-wide expansions and the development of stronger monitoring and evaluation capacity remain key areas of focus within this policy formulation. The latter focus has resulted in a multi-pronged approach, amalgamating inputs from various government and private stakeholders and aimed at developing effective data streams to support effective decision making. In line with this approach, the policy document, among other data gathering and knowledge mobilising activities, recommends the establishment of a long-term M&E programme around the public and science.

Within a global *post-truth* climate, the focus remains on the development of a critical audience for science in South Africa. This requires the coordinated response proposed by the DSI. Science communication and engagement would be coordinated on a greater scale, extending beyond the DSI and its related public sector entities. The inclusion of civil society, private business, higher education and the non-profit sector broadens the scope and beneficiaries of investments in the NSI. This in turn relates to more pervasive and substantial on-the-ground benefits to society and, in many respects, increases the democratisation of the scientific enterprise in South Africa. As a direct result of the importance of the NSI to nation building, addressing the inequalities within society and directing an increased pace of economic and democratic participation, the DSI proposes within this document a set of system-wide evaluations within the science promotion and engagement arena. These new data streams are essential to building the national system of innovation, identifying domestic successes and developmental priorities, providing an equal footing for greater international comparison and identifying a coordinated national assessment of the relationship between the public and science in South Africa.

The policy ecosystem provides the landscape within which the public relationship with science is shaped. This chapter has outlined the evolving policy context in the country and highlighted the key contemporary policies influencing and directing the future of science engagements in South Africa.

3. THEORETICAL DEBATES AROUND THE PUBLIC RELATIONSHIP WITH SCIENCE

3.1 Introduction: Understanding the Public Relationship with Science

The study of how the public engages with science has evolved significantly in the last 50 years (Miller, 2001; Bauer et al., 2007; Reddy et al., 2009). Despite the global and often controversial history of science within a social context, much of the study of how the public understands and assimilates science has been focused on the American and European context. The national science system, together with its study of how science influences society prior to 1994, has a history that is complex and relatively undocumented. Much of the historical context of the development of theoretical approaches to the study of the public understanding of science described below is directly due to the study of European and American science policy, political and social events in those regions, and their influence on empirical evolution in this research domain. In the South African context, the contribution in this area has predominantly been via surveys and related empirical work, as opposed to the magnitude of intellectual or theoretical work that has been conducted in the USA and Europe. It is widely accepted that the theoretical evolution of this research area incorporates three paradigms used in both the empirical understanding and the practical conceptualisation of research practice. Each of these paradigms focus on particular areas of the public relationship with science as well as on the particular traits of actors within the research practice. The following table provides an overview of these three paradigms.

Table 1: Research paradigms

Period and Research Paradigm	Research Areas
Science Literacy 1960s onward	Measures of literacy Educational policy
Public Understanding of Science after 1985	Knowledge and attitudes Attitude formation and change
Science and Society 2000 –present	Public participation Mediators of science Evaluations of impact

Adapted from Bauer, Allum and Miller (2007: 80)

The study of the public's relationship with science has changed over time, and 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) presented the argument that rather than assuming 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.

The following section provides a concise account of the evolution of method and theory within the field through the preceding 50 years.

3.2 Scientific Literacy

The critical period within the area of the public relationship with science emerged in the 1950s and 1960s. The history and global literature within this field of study are particularly rooted in the social and cultural settings of the United States of America and the United Kingdom. That noted, the development of the theoretical and empirical approaches within this area did benefit significantly from the early psychometric and related instrument development practices. This provides a significant global initiation point and given that this field involves the study of science within a society, highlights the critical importance of social context as a backdrop to the study of the public relationship with science.

In the United States, a crisis of legitimacy for science began to unfold during the mid-1950s and early 1960's. The intrinsic social value and contribution of science and technology were not actively appreciated by the population and policy makers. As a result, the scientific community had to obtain pledges of support from the public for S&T projects, particularly those of national importance (Laugksch, 1996; DeBoer, 2000; Wolf and Barton, 2004; Bauer et al., 2007). The crisis of legitimacy had initially been the result of significant threats to project support and funding. Political and public support is, however, highly 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 (Miller, 1983). As a result, the movement advocating enhanced *scientific literacy* within the US adopted an educational focus in pursuing this agenda into the latter part of the twentieth century.

In his definition of scientific literacy, Miller identifies three dimensions that were essential to be considered scientifically literate (1983; 1987; 1998). These include: a) knowledge of scientific facts, b) an understanding of scientific methods and c) an understanding of the relationship between science and society. In his definition, Miller contends that, aside from possessing scientific knowledge, a scientifically literate person should be able to distinguish valid scientific approaches from invalid ones, while similarly being able to locate scientific outcomes as value propositions in society. One of the defining elements of Miller's conception of *scientific literacy* is the rejection of superstition and the ability to distinguish science from pseudo-science. Bauer, et al. (2007) underlines how the notion of scientific literacy is constructed as the drive both for basic literacy through education and for the development of a more democratically active citizen through literacy. Laugksch (1996) also emphasised when he argued that there were three benefits to be derived from the development of basic scientific literacy,[7] namely, economic benefit, decision-making benefits as a consumer, and the democratic value in creating more involved and active citizenship.

While the key motivators within the scientific literacy movement relate to ensuring public support for scientific advancement through the adoption of the axiom 'the more they know the more they will love science' in accordance with an educational reform framework, the primary focus within scientific literacy research remains grounded in the psychometric testing of knowledge among citizens. This is operationalised through the use of quantitative, usually survey-based, methodologies. Recent innovations have similarly yielded qualitative approaches to introduce a greater degree of reflexivity within this research area (Wynne, 1991; Bauer, 2009). Fundamentally, these included quiz-like items, in various transmission and recording modes,[8] testing citizens' knowledge of scientific facts, considered as basic requirements for the outcomes of a school education. This provides an indication of broad public scientific literacy indicators often adopted in support of increased domestic educational investments. The US National Science Foundation (NSF) and later the Eurobarometer surveys, employed similar measures in order to develop early indicators of scientific literacy. Many of these have subsequently been adopted internationally, though not without contestation (Bauer, 2009; Raza et al., 2002).

7 In South Africa.

8 May include electronic forms, websites, mobile applications or public terminals.

These traditions hold that the public is *deficient* in terms of scientific knowledge. This contention goes further to assume that a public deficient in scientific knowledge, facts and an appreciation of the methods and modalities of science would not be effective participants in the science policy sphere. The further assumption is that a public with such a deficiency would be ill prepared to derive adequate benefit from scientific developments or to be empowered through knowledge-backed decision-making capabilities, and therefore not fully able to execute their civic duties (Burns et al., 2003). Miller, as others in the field at the time, proposed that it should remain within the ambit of the scientific community to correct this deficit, as lack of knowledge may lead to a negative appreciation of the value of science and thereby negatively impact on the progress of the scientific community in the long term (Miller, 1983). This proposal suggested a top-down flow of knowledge and a lack of effective two-way communication between scientific actors and the general public. The assumption of a public deficient in knowledge therefore gave rise to a growing scepticism within society.

Criticisms of the scientific literacy paradigm include: the value of life-long learning over school achievement only; and the latent contributions within *informal*, *indigenous* or *practical* scientific knowledge systems. At the same time the lack of cultural reflexivity highlights an inadequacy within the scientific literacy paradigm. In addition to these critiques, the scientific literacy paradigm further assumes a positive relationship between *public knowledge* and the *public relationship with science*, and in doing so does not make allowances for a negative relationship between the public and science (Reddy et al., 2009).

Therefore the scientific literacy approach, while still favoured in empirical studies, does have a number of shortcomings with respect to reflexivity, theoretical consistency with actual learning research and its influence on social attitudes, as well as negating the level of interest the public holds with regard to science and its role in society. Understanding the level of public knowledge of science contributes significantly to planning, education and down-stream social development, particularly in the Global South. While this remains valuable in contemporary society, significant advances have been proposed that aim to navigate many of the inadequacies presented by this research framework.

3.3 Public Understanding of Science

In the United Kingdom, the Royal Society Report (1985) describes the essential elements of the relationship between the scientific community and the public. The increasingly critical 'attitude' on the part of the public placed the scientific community and its continued growth at some risk, and reduced public investment in infrastructure related to S&T facilities. It further challenged the general interest of the public in scientific endeavours and outputs, careers in science, as well as the pipeline of suitably skilled scholars. The report recommended the establishment of the Committee on the Public Understanding of Science (CoPUS) to facilitate and develop schemes to understand public attitudes to science and enhance the communication of scientific information to the public. The work of CoPUS and the influence of the Royal Society Report extended the scope of the study area to incorporate a focus on public attitudes to science, thus adopting the name of the report, Public Understanding of Science (PUS).

While it continued to share many focal points with the scientific literacy framework, the theoretical evolution did hold some critical differences. The renewed focus was on understanding public attitudes to, as well as interest in, science, and how these related to scientific literacy in its overall impact on the science–public relationship. Consequently, the research focus and empirical direction for the *public understanding of science* framework holds that the public does not possess enough 'positive attitudes' about science, and this presumed negative attitudes were limiting interest, knowledge and support for science (Durant, 1999). For empiricists as well as research scholars working within this field, the evolution in theoretical direction expanded the research agenda from the myopic focus on literacy measures toward incorporating a greater share of understanding from *learning theory*, in understanding how the public(s) assimilate, use and filter knowledge within their specific contexts (Zinman, 1991). Following this, matters relating to science communication were increasingly the focus, as the quality, frequency and availability of communication was seen to be influential in developing more positive public attitudes.

The theoretical interest advanced from the development of knowledge measures to include the development of more reliable assessments of public attitude to S&T issues. This shift encountered the significant challenge of the multi-dimensionality of the science–public relationship – with recognition of the multitude of influences on this interactive space, in addition to knowledge measures.

These considerations advanced the empirical direction of the study of the public understanding of science toward adopting a contextual approach, recognising that the initial linear models of scientific literacy were inadequate in the context of understanding public attitudes. What it achieved, beyond the revised focus on public attitudes and interest, is a mobilisation of the scientific workforce toward adopting a more public-focused communication and knowledge dissemination approach. This advancement in theory, scientific attitude and dissemination practice was aimed at enhancing public awareness and opening up spaces for continued dialogue on scientific areas between the public and the scientific community (Durant, Evens and Thomas, 1989).

While the PUS paradigm demonstrated significant advances on the scientific literacy model in terms of theoretical consistency and empirical relevance, it was not without some criticism. Critics contend that this approach attributes the public with a deficit in positive attitudes (Bauer, 2007). The proposed solution to correcting this deficit is seen to be enhanced communication from scientists, so that the public is able to develop more positive attitudes as a means to mitigate the downstream impacts of a loss of public support for scientific work (Miller, 2004). The PUS approach continued to address many of these concerns within a one-directional flow of information – presupposing a knowledge, and therefore a power, differential within the public–science relationship. Despite these debates, the *public understanding of science* research framework lends itself to understanding the science–public relationship in clearer terms.

Building greater public support and more positive attitudes to science remain a critical objective. It is clear from international evidence that a global paradox is emerging – despite broader access to information and public knowledge, the general public appears to demonstrate lower interest in scientific information (Pouris, 2001/2006; Japan Science Report, 2001; India Science Report, 2005; Eurobarometer, 2010; NSF, 2016). This trend bolsters the drive to augment an empirical appreciation of why and how the public engages with scientific information, as well as how to best enhance public engagement toward fostering a more balanced public understanding of science.

3.4 Science in Society

During the late 1980s and early 1990s a number of significant social and geopolitical events attracted considerable public attention. The influence of the BSE[9] crisis in the UK, the debate surrounding animal cloning, genetically modified foods, as well as a number of other scientifically-based areas of public concern raged not only within the scientific community but within public spaces and popular media (Stastny, 2005). More contemporary concerns relate to DNA modification, nuclear energy, artificial intelligence[10]

9 ‘Mad Cow Disease’ (Bovine spongiform encephalopathy).

10 These debates extend beyond privacy, toward personal security, financial and economic productivity and labour market concerns. All of which relate to the conceptual formulation of trust in the scientific community and areas of technology.

and vaccines. This attracted substantial public interest, and consequently had economic impacts[11] beyond the borders of the UK. A similar pattern of public concern was evident within the area of nuclear research in the immediate post-World War II years. As the 1990s progressed and the influence of technology on society became increasingly more pervasive, these concerns became central to the scientific community as a direct challenge to the future direction and support for the enterprise.

The interest in the public understanding of science and scientific literacy did not diminish, as much as the research agenda expanded to include greater emphasis on the role and influence the public may have on science policy and the support for large-scale public investments. This enhanced research agenda recognised the value and importance of the public and no longer viewed the public as incidental to the scientific enterprise (Pardo and Calvo, 2002). This change in focus reframed the study of the public–science interaction as more of a dialogue than a one-directional flow of information. Miller (2001) highlights the shift in asserting that knowledge flows became increasingly bi-directional, within a social contextual approach, and the value of public opinion, local knowledge and social realities were increasingly adopted to promote and direct scientific work. By this point, indicated in the numerous empirical investigations conducted within Europe and the US, together with the impact of the many social crises unfolding by the mid-1990s, public interest in science had increased significantly (Burns et al., 2003). That being the case, measures of public understanding of science and, to a certain degree, public confidence in scientific knowledge had demonstrated a decreasing pattern. Within this climate of low measured scientific illiteracy, Sturgis and Allum (2004) note the appearance of rising 'public scepticism about the benefits of science' as well as an increase in negative attitudes in relation to technological advancements.

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). Within the report, the notion that science is a socially constructed enterprise, operating within specified contexts and responding to the realities experienced by citizens, however, had been operationalised within a social vacuum devoid of influence or input from social actors (Bauer et al., 2007; Miller, 1998). The source of this mistrust emanated from the scientific community not recognising that attitudes and perceptions of science are based on more than just measured scientific knowledge, but are highly impacted by a series of values, contextual and related social influences. The most important among these relate to the potential risks and benefits associated with numerous technological advancements – particularly as they relate to proximal issues rather than more distal areas of scientific influence.[12] The influence of public attitudes and public perceptions then had a significant influence on the future direction and in particular public funding of research activities.

This revised model calls for an increase in public-focused communication – but in a bi-directional format. Under this approach, the heterogeneity of the general citizenry was more accurately appreciated and mobilised the scientific community to adopt more public-centric science communication strategies. This engages the public in more meaningful ways, and earlier in the research process. While the earlier models attributed a knowledge and positive-attitude deficit to the public, within the *science and society* model the deficit attribution is one of trust and public engagement on the part of the scientific community. The *science and society* framework 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,

11 The bans imposed on British beef impact on production and jobs as well as trade and trans-European health and safety concerns.

12 Here we include issues related to, but not limited to, health, the environment and human development.

illustrating the misconceptions that perpetuated this perceived public deficit notion in terms of the public understanding of science and scientific literacy paradigms (Reddy et al., 2009).

Building this trust requires the adoption of new strategies and approaches toward harnessing public support and ensuring earlier public participation in important policy and research decision-making processes. This has been the major thrust within the Science and Society framework (now referred to as the Science *in* Society Framework). These enhanced approaches include fora such as science cafes, citizen juries, pressure groups, NGOs as well as media partners to enhance the reach and relevance of scientific work vis-à-vis a scientific audience. The essential value here drives a connectedness within the expanded stakeholder group – which includes larger elements of the general citizenry. These new opportunities make express allowance for feedback mechanisms and increasingly direct participation in the decision-making spaces inside the scientific community. The influence of social media[13] and related technological advances have broadened the scope of mediums used to access and influence significant scientific events. These activities extend beyond research projects and research outputs to include issues related to research policy, communication and national scientific productivity profiles as important points of influence in the science–public interaction space. This approach empowers the public to become active contributors to scientific disciplines, thereby enhancing their educational, employment and participatory prospects within a system that rewards the highly skilled.

The case for scientific literacy and the development of positive attitudes remain central in this research paradigm. However, the call within the scientific community has evolved to adopt a more interactive space for shared learning to overcome the perceived obstacles within the public–science interaction space. The recent increase in interest in scientific media across various platforms, from journal publications to social media and blogs, has offered a new avenue to share ideas and information on scientific work for both the scientific community and the general public (Blik and Goldstein, 2013). While this does not always have the intended reach owing to issues of 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.

The pervasive nature of social media[14] as well as the heightened degree of access this provides the general citizenry represents a significant shift in the technology-society sphere that provides enhanced access and data interaction modalities between the public and the scientific community. These techno-human interaction points with the scientific community require a significant shift from the simple linearity that the deficit models had espoused. A more diffuse view of the manners and modalities of interaction, information assimilation, attitude formation as well as value-laden social context of an information ecosystem all coexist toward influencing the general public understanding of science within the contextual approach. Important dimensions of this remain dialogue, negotiation, compromise and mutual accommodation toward establishing long-term relationships with critical public and social stakeholders within communities (Borchelt and Hudson, 2008).

Among the modes adopted within the science and society framework, often incorporating elements of technology and geographically relevant knowledge systems, is the emerging area of citizen science. Hecker et al. (2018) describe this area as an amalgamation of public engagement activities, public understanding, crowd-sourcing and community science. Beyond this, citizen science is a movement where the public is brought into the upstream research process, providing conceptual guidance, local information and, in many

13 Twitter, LinkedIn, Facebook, WhatsApp.

14 This does not discount the important and often harmful influence of *'fake news'* and obscure or inaccurate reporting within the non-professional media space.

instances, on-the-ground support with data collection and management operations. Globally, the number of citizen science programs and practitioner platforms has expanded exponentially – particularly in Europe and the Asia Pacific regions. These programmes (in some respects) create employment and educational opportunities, and provide a greater reach of scientific information, as well as ensuring the proliferation of oral histories and knowledge engrained within the social and cultural practices of communities. The field has encountered much support and has increasingly become professionalised (as examples see: European Citizen Science Association; Citizen Science Association USA; Australian Citizen Science Association). What these programmes have achieved is greater community and public involvement in science, greater promise in the value and contribution that science has for society, more employment opportunities, fostering a greater sense of trust in the ideals of science, and greater support within the science policy environment (Hecker et al., 2018).

Beyond the deficit models, the contextual approaches include a greater focus on public engagement than the earlier focus on information sharing and delivery. Within this approach engagement not only encapsulates the bi-directional flow of information and sharing of experience, but further aims to share methods, practices and ownership of research outcomes. The contextual models in the science in society framework acknowledge the historic assumptions of the scientific community as shortcomings in the engagement of the general citizenry. The framework goes further than this through the active engagement of the public, the highlighting of the interactive nature of the scientific process, the understanding of expertise outside the domain of formal scientists[15] and the attribution of a sense of authority to the public in terms of the direction and purpose of science in society (Brossard and Lewenstein, 2010).

These ideals therefore support more than just the notions of building public support for the purposes of ensuring policy and funding for the continued survival of the scientific enterprise. This reprises the motivation and purposes of the scientific enterprise itself – toward building a more informed, critical and active citizen base that contributes not only to the advancement and evaluation of research, but also to the values and progress of the societies they inhabit. This approach democratises learning spaces moving toward a free-choice model, where the emergence of science centres, science outreach and citizen science activities play a central role. Science communication and outreach practices involve the community in decision making, steer the conversations within a social context, and create a sense of purpose and value in communities subject to and hosting research physically as well as culturally.[16] It also raises significant research areas surrounding the psychology of attitude formation, social learning, developing and maintaining trust, and the understanding of perceptions of knowledge producers in relation to hosting public engagement activities.

This evolution within the study of the public understandings of science has been described by Fuller (2000) as a 'new deal with society', drawing both sides of the public–science chasm into a better working relationship.

3.5 Concluding Comments

This section has presented the evolution of the three paradigms or frameworks within the public relationship with science sphere: science literacy, public understanding of science, and most recently science in society. Each paradigm built on the critique of the previous paradigm, attempting to develop an enhanced relationship between the public and science, as a crucial element within the scientific and technological development of society. The theoretical evolutions since the scientific literacy movement first emerged

15 Local and indigenous knowledge holders.

16 This is of particular importance when considering indigenous knowledge systems, oral knowledge as well as environmental and location specific data gathering that form essential cultural centre points within communities. When this leads to effective commercialisation of technologies or scientific advances, this framework of understanding emphasises the importance of these considerations.

have accelerated significantly along the path to the development of the science in society paradigm. This could then be seen to have transitioned within three waves of theoretical evolutions, the first wave being the pursuit of increased scientific knowledge under the scientific literacy paradigm. This wave was followed by the inclusion of attitudinal, interest and related contextual measures within the public understanding of science movement. Among the proponents of the science in society paradigm, contemporary focus has been on understanding trust–ecosystems within society, building connected science systems including public stakeholders, applying technology to learning and outreach activities and promoting a democratised scientific approach through citizen science programmes. All these approaches have contributed iteratively to our shared understanding of the public understanding of science. As technology continues to evolve, with a leading and lagging adoption space, this theoretical and practical understanding within the science–public relationship will become an increasing research and social focus.

4. INTERNATIONAL SURVEYS ON THE PUBLIC AND SCIENCE

4.1 Introduction

Globally, there has been recognition of the importance of measuring and understanding the relationship between the public, and science and technology (S&T). Numerous studies have been conducted internationally in this area over five decades, with an increased focus over the last twenty years. The form of these studies depends on their environmental and theoretical context, with some surveys being conducted on a regular basis, and others being once-off data collection tools. The US has developed science and engineering indicators, and the European Union (EU) has developed the Eurobarometer series which has included various questions related to science and technology (S&T) over the years. India and China have set a precedent for measuring the public's relationship with science in the developing country context, whereas countries such as Malaysia and Brazil have also conducted surveys related to public perceptions of S&T in the developing world context. A number of international studies spanning various continents have also been undertaken and incorporate both developed and developing countries. Other examples discussed below include the Relevance of Science Education (ROSE) project and the Programme for International Student Assessment (PISA). These are international comparative studies which examine what learners perceive as the important factors affecting S&T education. Table 2 provides a list of some of the studies that have been undertaken internationally on the public and S&T.

Table 2: International surveys conducted on the public and S&T

Context	Survey	Years
Asia	Climate Asia surveys	2012
Australia	Australian Attitudes to Climate Change: 2010–2014	2010–2014
	The Australian Beliefs and Attitudes towards Science Survey	2017, 2018
Brazil	Public Perceptions of Science and Technology	2006
	Percepção pública da C&T – 2015 Ciência e tecnologia no olhar dos brasileiros (Public Perception of S&T – 2015 Science and Technology in the Eyes of Brazilians)	2015
	Mudanças climáticas: O que pensa o brasileiro (Climate Changes: What the Brazilian thinks)	2015
	What do Young Brazilians Think of Science and Technology?	2019
Canada	Public Survey of Science Culture in Canada	2013
Canada & USA	Canada–US survey on Biotechnology	2005
China	Chinese National Survey of Public Scientific Literacy	1992, 1994, 1996, 2001, 2003, 2005, 2007, 2010, 2015, 2018
	China Science and Technology Indicators	2004
Europe	Special Eurobarometer Europeans and Biotechnology	1991, 1993, 1996, 1999, 2002, 2005, 2010
	Special Eurobarometer: European Science and Technology	1992, 2005, 2010
	Special Eurobarometer: Attitudes towards Radioactive Waste	1998, 2001, 2005 2008

Context	Survey	Years
Europe	Special Eurobarometer: Attitudes of European Citizens towards the Environment	1999, 2004, 2007, 2011, 2014, 2017
	Special Eurobarometer 203/ Wave 60.2: Illegal and Harmful Content on the Internet	2003
	Special Eurobarometer 225/Wave 63.1: Social Values, Science and Technology	2005
	Special Eurobarometer: Scientific Research in the Media	2007
	Flash Eurobarometers: Attitudes towards Biodiversity	2007, 2013
	Special Eurobarometer: Climate Change	2008, 2009, 2011, 2013, 2015, 2017
	Flash Eurobarometer: Attitudes of Europeans towards Resource Efficiency	2011
	Flash Eurobarometer 367: Attitudes of Europeans towards Building the Single Market for Green Products	2012
	Flash Eurobarometer 360: Attitudes of Europeans towards Air Quality	2012
	Flash Eurobarometer 344: Attitudes of Europeans towards Water-related Issues	2012
	Flash Eurobarometer 361: Chemical	2012
	Special Eurobarometer: Cyber Security 290/404/423/464a	2012, 2013, 2014, 2017
	Special Eurobarometer: Responsible Research and Innovation (RRI) Science and Technology	2013
	Flash Eurobarometer 388: Attitudes of Europeans towards Waste Management and Resource Efficiency	2013
	Special Eurobarometer: Public Perceptions of Science, Research, and Innovation	2014
	Flash Eurobarometer 404: European Citizens' Digital Health Literacy	2014
	Special Eurobarometer 427: Autonomous Systems	2014
	European Social Survey: Public Attitudes to Climate Change	2016
	European perceptions of Climate Change (France, Germany, Norway, UK)	2016
	Special Eurobarometer: Attitudes towards the Impact of Digitisation and Automation on Daily Life	2017
	Special Eurobarometer: Europeans' Attitudes towards Internet Security	2018
France	*La Recherche* and *Le Monde* Climate Survey (French Research Journal and *Le Monde* newspaper climate survey)	2015
Germany	Wissenschaftsbarometer (German Science Barometer)	2014, 2015, 2016, 2017, 2018
India	India Science Report: Science Education, Human Resources and Public Attitude towards Science and Technology	2005

Context	Survey	Years
Israel	Science and Technology in the Israeli Consciousness	2006
	Perceptions and Attitudes of the Israeli Public about Science, Technology and Space	2016
Italy	Annuario scienza tecnologia e società (Technology and Society Science Yearbook)	2005–2019
Japan	2001 Survey of Public Attitudes towards and Understanding of Science and Technology	2001
	Survey of Scientific Literacy	2011
Korea	Survey of Public Attitudes towards an Understanding of Science and Technology	2004, 2006, 2008, 2012
Malaysia	Public Awareness of Science, Technology and Innovation (STI) Malaysia	1994, 1996, 1998, 2000, 2002, 2004, 2014
Mexico	Encuesta sobre la percepción pública de la ciencia y la tecnología (Survey on public perception of science and technology)	2015
New Zealand	Public Attitudes towards Science and Technology	2002, 2005, 2010, 2014, 2017
Russia	Russian Public Opinion on the Knowledge Economy	1995, 1996, 1997, 1999, 2003
Spain	Percepción social de la ciencia y la tecnología (Social Perception of Science and Technology in Spain)	2002, 2004, 2006, 2008, 2010, 2012, 2014, 2016, 2018
Sweden	VA (Vetenskap and Allmänhet [Science and Public]) Barometer	2002, 2006–2019
UK	Science and the Public (OST/Wellcome Trust)	2000
	Information and Attitudes: Consulting the Public about Biomedical Science	2000
	Science in Society (MORI/OST)	2005
	Public Attitudes to Science 2008 (RCUK/DIUS)	2008
	Wellcome Trust Monitor: Tracking Public Views on Medical Research	2009
	Wellcome Trust Monitor Wave 2: Tracking Public Views on Science, Biomedical Research and Science Education	2012
	Wellcome Trust Monitor Report Wave 3: Tracking Public Views on Science and Biomedical Research	2015
	Public Attitudes to Science (Ipsos MORI)	2011
	Public Attitudes to Science 2014 (Ipsos MORI)	2014
	Public Attitudes to Chemistry	2015

Context	Survey	Years
USA	Science and Engineering Indicators	1979– 2018 (every two years)
	Various Surveys (Gallup Organization)	1982–2017
	Media and Political Surveys (Various) (Pew Research Center for the People and the Press)	1985–2016
	Biennial News Consumption Survey	1996–2008
	Virginia Commonwealth University Life Sciences Survey	2001–2008
	General Social Survey: S&T Module	2006, 2008, 2010, 2012, 2014, 2016
	Climate Change in the American Mind	2008–2016
	National Surveys on Energy and Environment	2009–13, 2016–17
	General Public Science Survey, Separate Survey of American Association for the Advancement of Science Members	2014
Various countries	Programme for International Student Assessment (PISA)	2000/2002, 2003, 2006,2009/2010, 2012
Various countries	Relevance of Science Education (ROSE)	
15 countries	BBVA Foundation International Study on Attitudes Towards Stem Cell Research and Hybrid Embryos	2007/2008
Various countries	BBVA Foundation International Study on Scientific Culture	2011
Various countries	Public Attitudes To Life Sciences Research in Six European Countries	2018
Various countries, including SA	Wellcome Global Monitor: How Does the World Feel about Science and Health?	2018
14 countries, including SA	3M State of Science Index	2018, 2019

**** This list is not exhaustive, but gives an overview of the international public, science and technology, and research landscape. See Appendix A for a more detailed table.***

4.2 USA National Science Foundation: Science and Engineering Indicators

The National Science Foundation (NSF) in the US releases *science and engineering indicators* every two years. In the context of a move toward more knowledge-intensive economies worldwide, and increasing global collaboration and competition in science and engineering (S&E), the report focuses on international and domestic science, engineering and technology (SET) dynamics. The biennial report is presented to Congress, and provides a broad base of quantitative information about SET in the USA. Each report focuses on science, engineering and technology at all levels, including basic and higher education, the labour force, research and development, and industry and technology. One of the elements reported on relates to public attitudes towards and understanding of SET. The study acknowledges that a public scientific culture can give a country a competitive advantage in a globalised world. An increased public understanding of science and technology (S&T) is one important aspect of such a scientific culture (NSF, 2008).

Discussions related to S&T often focus on the potential risks and benefits of existing and new technologies, as well as on moral issues surrounding the adoption of certain scientific processes and technologies. The NSF report (National Science Board, 2018) highlights that society will better be able to address potential concerns when the nature of these concerns is discussed and understood. The opinions of citizens with regard to the potential benefits and risks of S&T may also have an impact on the types of S&T that are ultimately developed or used, as they play a role, directly or indirectly, in the resources devoted to S&T research and development. Furthermore, individuals select their careers based on their interests; and S&T can play a role in shaping what young people learn about science and their attitudes towards it (National Science Board, 2018).

The most recent set of indicators was published in 2018. Chapter 7 of the report focused on Science and Technology: Public Attitudes and Understanding. It explored knowledge and attitudes concerning S&T matters and compares this information to what the public should know about S&T. The chapter explores public engagement with S&T, including interest in S&T news, sources of information, and involvement in informal S&T activities. It also reports on indicators of public knowledge, including factual knowledge of S&T and people's understanding of the scientific process. Data are presented on attitudes relating to public support for S&T, including support for government funding of research and confidence in the scientific community's leadership. Attitudes towards issues in which S&T play a key role, and areas of research and technology are also explored, such as climate change, nuclear power, the environment, energy, and the use of animals in scientific research, genetically engineered food, stem cell research, and cloning (National Science Board, 2018).

The Science and Engineering Indicators Report uses various sources of information for each section. The 2018 chapter used only surveys involving probability-based samples. The General Social Survey (GSS), which is a nationally representative survey, provided an important source of data for this chapter. The GSS investigates the attitudes and behaviour of the US population using face-face interviews. The other primary sources of US data include studies by Gallup and the Pew Research Center, which use predominantly telephonic interviews (both landlines and cell phones). Among the other sources, two internet-based surveys also provided data for the chapter, one by Growth for Knowledge (GfK) and one by Pew Research Center. Probability-based sampling for their surveys is usually done using telephone and mail to invite people to be part of the panel, and respondents are then probabilistically selected for individual surveys (National Science Board, 2018).

The chapter presents patterns, trends and variations within the US, and provides comparisons with other countries or regions (National Science Board, 2018). Table 3 presents the subject areas covered in Chapter 7 and highlights some of the Report's findings.

Table 3: Areas assessed in 2018 Science and Engineering Indicators report

Subject area	Summary	Examples of findings
Interest, Information Sources, and Involvement	• Public Interest in S&T • S&T Information Sources • Involvement	'Very interested' in new scientific discoveries (42%); use of new inventions and technologies (42%); medical discoveries (60%). Sources of S&T information: 69% online; 12% television; 3% newspapers.
Public Knowledge about S&T	• Scientific Terms/Concepts • Reasoning and Understanding the Scientific Process. • Pseudoscience • Understanding of Scientific Research	63% correctly answered an average of 5.6/9 true-or-false or multiple-choice items. 31% reported a clear understanding of 'what it means' when they 'read or hear the term scientific study'.
Public Attitudes about S&T in General	• Promise of and Reservations about S&T • Funding of Scientific Research • Confidence in Science Community's Leadership	72% saw more benefits than harm from science; 91% agreed that 'S&T will create more opportunities'; 51% agreed that 'science makes our way of life change too fast'. 40% expressed 'a great deal of confidence' in leaders of the scientific community.
Public Attitudes about Specific S&T-Related Issues	• Environment, Climate Change, Energy, Genetically Engineered Food, Nanotechnology, Stem Cell Research and Cloning, Animal Research	47% worried a 'great deal' about the quality of the environment. 45% worried a 'great deal' and 21% a 'fair amount' about global warming. 51% thought that the benefits of nanotechnology will be greater than the harms.

Adapted from National Science Board (2018)

When interpreting the results, it is important to consider the education levels of the population. In 2017, the percentage of the population 25 to 64 years old who had completed secondary school in the US was 91%, while 46% of the population in the same age range had attained a post-secondary degree (National Center for Education Statistics, 2019). In the case of the South African population over the age of 20 years, 31% have completed secondary education and 14% have completed a post-secondary qualification (StatsSA, 2016).

These reports allow for data- and evidence-based discussions to take place in relation to what Americans think and know about topics related to science, technology, and engineering. The comparisons included, such as those between groups of people, between countries and over time, provide an understanding of the global landscape within which the US is situated, and where the US may have had successes or further intervention is required (National Science Board, 2018). The National Science Foundation also provided a significant amount of publicly accessible date together with an array of resources for understanding the data on their website.

4.3 Eurobarometer

The *Eurobarometer* is a series of multi-topic surveys which have been conducted regularly for the European Commission since 1973, across all EU member countries. The standard Eurobarometer is conducted annually and investigates the opinions of the public in EU member states in terms of their attitudes towards European integration, policies, institutions, social conditions, health, culture, the economy, citizenship, security, information technology, and the environment, among other topics (European University Institute, n.d.). Standard and Special Eurobarometer surveys use face-to-face interviews in respondents' national language, with approximately 1000 individuals in each EU member state. The Eurobarometer has included various modules on attitudes to a range of areas related to S&T, such as biotechnology, climate change, the environment, biodiversity, nuclear energy, scientific research in the media, the impact of digitisation and automation, internet security, and science research and innovation. Since 2005, each Eurobarometer focusing on S&T has surveyed between 24 000 and 33 000 people. Given the length of time over which the Eurobarometer has been conducted, the survey provides insight into trends and the evolution of public opinion (European Parliament, n.d.).

Research showed a gap between science and society: Europeans feel they are not well informed and have limited involvement in S&T. This has led to concerns and scepticism surrounding specific S&T issues. In order to tackle such issues, in December 2001, an action plan called 'Science and Society' was adopted within the European Research Area. Some of the main objectives of this action plan are: 1) Promoting the scientific education and culture of European citizens; 2) Bringing scientific policy closer to citizens and strengthening citizen participation in the debates raised by scientific advances; 3) Involving more women, who are not sufficiently represented in scientific development; and 4) Strengthening the ethical basis of scientific and technological activities and detecting risks inherent in progress in order to put responsible science at the heart of policy making (NSF, 2018). A need to increase the dissemination of scientific information to motivate Europeans to become more involved in science was identified. This led to the 2005 Special Eurobarometer on Europeans, Science and Technology (European Commission, 2005). It is likely that this drive towards S&T knowledge and understanding influenced the various Special Eurobarometers focusing on S&T thereafter.

In this section, we focus on some of the most recent S&T topics included in the Eurobarometer between 2014 and 2019.

Public Perceptions of Science, Research and Innovation (Special Eurobarometer 419, 2014)

The EU committed to spending nearly €80 billion on research and innovation through the EU Research and Innovation programme Horizon 2020, which began in 2014. Despite a slight reduction in the EU's overall budget, this represented a 30% increase on the amount spent on scientific research over the preceding seven-year period. This Special Eurobarometer aimed to inform Horizon 2020 by establishing which areas of focus were of most concern to citizens in order to focus on them. The survey was requested by the European Commission, Directorate-General for Research and Innovation, and received 27 910 responses (European Commission, 2014).

Attitudes towards the impact of digitisation and automation on daily life (Special Eurobarometer 460, 2017)

In the EU, digital technology has had an increasing impact on all aspects of social and economic life, 'from the increasing use of robots and artificial intelligence, to eHealth and online public services' (European Commission, 2017a). The report noted that in this context, it is important for citizens to have the skills and confidence to be able to make the most of these digital technologies and opportunities. At the same time, there are concerns about the increasing impact of digital technologies in daily life. This Special Eurobarometer was requested by the European Commission, Directorate-General for Communications Networks, Content and Technology, and was designed to gauge public opinion on a range of areas related to digital technologies, robots and artificial intelligence. There were 27 901 respondents to the survey, which followed on from previous surveys in the area in 2012 and 2014 (European Commission, 2017a).

Attitudes of European citizens towards the environment (Special Eurobarometer 468, 2017)

The EU's Europe 2020 strategy contains critical environmental objectives, as well as a commitment to sustainability, in order to address the environmental problems facing Europe and the world. The strategy's flagship initiative of 'engendering a resource-efficient Europe supports a shift towards a low-carbon, low-impact economy' (European Commission, 2017b). To inform this process, and to assist the European Commission in delivering the environmental goals of Europe 2020, this survey examined citizens' perceptions of the environment and environmental issues, and how these issues might best be addressed. The 2017 survey was requested by the European Commission, Directorate-General for Environment. There were 27 881 respondents. Three previous Eurobarometer surveys were conducted on the environment, in 2007, 2011 and 2014 (European Commission, 2017b).

Europeans' attitudes towards Internet security (Special Eurobarometer 480, 2018)

Cybercrime has become an increasing problem, estimated to result in the loss of billions of euro per year, as well as placing increasing strain on law-enforcement response capability. This problem is being compounded by the increasing use of the Internet, and is likely to increase significantly unless tackled effectively. In response, the European Commission, in co-operation with EU Member States and other EU institutions, designed a coordinated policy. EU legislative actions against cybercrime address issues such as attacks against information systems, online offensive material and child pornography, online privacy, and online fraud and counterfeiting. This Special Eurobarometer survey aimed to understand citizens' awareness, experiences and perceptions of cyber security issues. The survey, which had 27 339 respondents, was requested by the European Commission, Directorate-General for Migration and Home Affairs. It was partly based on three previous surveys on cyber security in 2013, 2014 and 2017 (European Commission, 2018).

Climate change (Special Eurobarometer 490, 2019)

According to the Climate change, impacts and vulnerability in Europe 2016 report by the European Environment Agency, climate change is having an impact on ecosystems, economic sectors, and human health and well-being in Europe (European Commission, 2017c). Taking action to address climate change is one of the top priorities for the EU, and they have committed to being a leader in global climate change action. After the 2015 United Nations Climate Change Conference (COP21), the EU set itself ambitious greenhouse gas emissions reduction targets for 2030, over and above its targets for 2020, under a wider 2030 climate and energy package (European Commission, 2017c). By 2019, the EU had made strides towards meeting the targets under its 2020 climate and energy package. In November 2018, the European Commission unveiled its long-term strategic vision for a prosperous, modern, competitive and climate-neutral economy by 2050 (European Commission, 2019). This survey was requested by the European Commission, Directorate-General for Communication, and conducted with 27 655 respondents. Previous rounds of the Eurobarometer survey on climate change were conducted in 2008, 2009, 2011, 2013, 2015 and 2017 (European Commission, 2019).

The table below provides the subject areas, and some examples of the findings from each of the Special Eurobarometers discussed.

Table 4: Some S&T topics included in the Eurobarometer (2014–2018)

Science, Research and Innovation (Special Eurobarometer 419, 2014)		
Subject area	**Summary**	**Examples of findings**
Personal scientific background	Studying science	A majority of Europeans (56%) studied science or technology, at school (44%), university or college (16%), somewhere else (3%).
Priorities for science and technological innovation over the next 15 years	Priority areas for S&T	Top priorities for S&T innovation: health and medical care (55%); job creation (49%); education and skills (33%); protection of the environment (30%); energy supply (25%); availability and quality of food (25%).
Impact of society, science and technological innovation on different areas of activity	Impact on various areas, including: climate change; job creation; energy supply; health and medical care; transport and transport infrastructure; education and skills	At least half expect that, 15 years from now, S&T development will have a positive impact on areas such as: health and medical care (65%), energy supply (58%), protection of the environment (57%), fight against climate change (54%).

Impact of digitization and automation on everyday life (Special Eurobarometer 460, 2017)		
Subject area	**Summary**	**Examples of findings**
Impact and use of digital technologies	• Impact of digital technologies • Factors stimulating the use of digital technologies	75% thought that the most recent digital technologies have a positive impact on the economy, 67% thought they have a positive impact on their quality of life, and 64% thought they have a positive impact on society.
Digital skills	• Everyday use of digital skills • Digital skills and labour market	71% considered themselves sufficiently skilled in the use of digital technology in their daily lives.
Attitudes towards content on online social networks	• Trustworthiness of content published on online social networks • Use of fact checking websites	Only 7% considered stories published on online social networks are generally trustworthy.
Attitudes towards robotics and Artificial Intelligence (AI)	• Perception of robots and AI • Attitudes towards robots and AI • Perceived impact on labour market	61% had a positive view of robots and artificial intelligence, whereas 88% agreed that these are technologies that require careful management.
Digital health and care	• Online access to medical or health records	In the preceding 12 months, 18% had used health and care services provided online 52% would like online access to their medical and health records.
Cyber security	• Actions taken due to cyber-security concerns • Cyber security as a factor in purchase of IT products	Amongst Internet users, the most common actions in response to security concerns were installing or changing antivirus software (45%), being less likely to give personal information on websites (39%), only using own computer (36%), or only opening emails from people and addresses they know (35%).

The environment (Special Eurobarometer 468, 2017)		
Subject area	**Summary**	**Examples of findings**
General attitudes towards the environment	• Importance of environmental protection • Main concerns • Main sources of information	94% said that protecting the environment is important to them personally. Most important environmental issues: climate change (51%), air pollution (46%) and the growing amount of waste (40%).
Impact of environmental issues	• Environmental issues and their effects on life and health • Impact of plastic products • Impact of chemicals	81% agreed that environmental issues have a direct effect on their daily life and their health.
Action to tackle environmental issues	• Tackling environmental problems • Individual action • Should big polluters be responsible? • Role of actors in protecting the environment • Tackling plastic waste and littering	Most effective ways of tackling environmental problems: investment in research and development to find technological solutions (35%), ensuring better enforcement of legislation (31%) and introducing stricter environmental legislation (30%). 87% agreed that as individuals, they can play a role in protecting the environment in their country.
EU and environmental protection	• Preferred level of decision making • Attitudes towards the role of the EU in environmental protection • Attitudes towards EU financial support	67% thought that environmental decisions should be taken jointly within the EU.
Ecolabels[17]	• EU and national ecolabels: aided recall • Ecolabels and products purchases	27% said they have seen or heard about the EU Ecolabel. 32% said ecolabels play an important role in their purchasing decisions.
Air pollution	• Perceptions on air quality • Tackling air pollution • Personal action to reduce harmful emissions • Preferred level of decision-making	47% thought that air quality in their country had deteriorated over the preceding ten years. 48% felt that the issue of air pollution can best be addressed at the EU level.

Internet security (Special Eurobarometer 480, 2018)		
Subject area	**Summary**	**Examples of findings**
Internet use	• Frequency of Internet access • Means of Internet access • Online activities	73% use the Internet daily, with 84% accessing the internet using smartphones. Main activities: access email (80%), read news online (69%), access social networks (62%).
Concerns about internet interactions	• Concerns • Impact on behaviour • Impact on security of online accounts	Most common concerns: misuse of personal data and the security of online payments (both 43%).

17 'Ecolabelling' is a voluntary method of environmental performance certification and labelling. Ecolabels are used to identify products or services proven environmentally preferable overall, within a specific product or service category (https://globalecolabelling.net/what-is-eco-labelling/).

Internet security (Special Eurobarometer 480, 2018)		
Subject area	**Summary**	**Examples of findings**
Awareness and experience of cyber crimes	• Level of knowledge • Attitudes to cyber security • Concerns about becoming a victim • Perception of specific cyber crimes	51% considered themselves well informed about cybercrime. 79% believed that there is an increasing risk of being a victim of cybercrime (79%).
Fighting cyber crime	• Awareness of other people who have experienced cyber crime • Frequency of being a victim • Action taken victims of a cyber crime • Children protection	54% knew someone who had been a victim of cybercrime. Two most common situations experienced: receipt of fraudulent emails or phone calls (34%) and discovering malicious software (33%).
Perceptions of institutions' responsibility to provide assistance to citizens	• Knowledge of official website for reporting cybercrimes • Actions taken in case of being a victim	77% were not aware of the existence of a website or e-mail address for reporting cybercrime. Most would take action if they were the victim of cybercrime, particularly bank card or online banking fraud (88%) and identity theft (87%).

Climate change (Special Eurobarometer 490, 2019)		
Subject area	**Summary**	**Examples of findings**
Perceptions of climate change	• Perceptions of climate change as a global problem • Perceived seriousness of climate change	60% saw climate change as one of the most serious global problems. 93% considered climate change a serious problem, 79% considered it a very serious problem.
Action to tackle climate change	• Responsibility for tackling climate change • Personal action • Types of individual action	When asked about specific actions to tackle climate change, 93% indicated taking at least one (most common: trying to reduce waste and regularly separate it for recycling (75%) and cutting down on consumption of disposable items whenever possible (62%). 55% felt that national governments are responsible for tackling climate change.
Attitudes towards fighting climate change and transition to clean energies	• Taking action on climate change • Reducing fossil fuel imports • Economic benefits of promoting EU expertise in clean • technologies • Public financial support – clean energies • Adapting to the adverse impact of climate change	84% agreed that more public financial support should be given to the transition to clean energies even if it means reducing fossil fuels subsidies. 70% respondents agreed that adapting to the adverse impacts of climate change can have positive outcomes for citizens in the EU.
Looking to the future	• Targets for renewable energy • Energy efficiency targets • A climate neutral Europe by 2050	A majority believed it is important for their national government to set targets to increase the amount of renewable energy used (92%) and provide support for improving energy efficiency (89%) by 2030.

Adapted from European Commission (2014; 2017a; 2017b; 2018; 2019)

The Eurobarometer provides regular information related to the public's attitudes towards various S&T topics in countries across Europe. It also allows for comparisons between the countries involved. As such, it is an important source of information for researchers, policy makers, organisations and individuals. Although levels of S&T understanding depend on national and cultural locations, the Eurobarometer administers a single instrument that does not take into account cultural impacts on S&T understanding. The measure has thus been criticised for being too normative – for measuring what scientific culture should be instead of what it is (Sturgis and Allum, 2004).

The different modules on S&T in the Eurobarometer have addressed a range of key issues affecting the EU population and other countries around the world, at the time of the studies, such as climate change, digitisation and automation, and environmental issues. They have also been able to provide information that informs various policies, strategies as programmes, such as the EU's Europe 2020 strategy, and the EU Research and Innovation programme Horizon 2020. Many of the special Eurobarometers discussed have been requested by the EU Commission, focusing on contemporary issues in Europe.

4.4 UK Public Attitudes to Science

Several surveys of the UK public's attitudes to S&T have been conducted over the years. The UK Charter for Science and Society called for the enhancement of public policy and debate through more extensive and purposeful engagement with all sectors of society, highlighting the importance of considering the views of the public alongside evidence presented by scientists and engineers. The Public Attitudes to Science (PAS) studies are one of the main ways in which the Department for Business, Innovation and Skills (BIS) has been able to monitor the views of the public, and assess the achievements of the Charter (Castell et al., 2014).

Public Attitudes to Science Studies

Public Attitudes to Science (PAS) 2011 (Ipsos MORI, 2011) was the fourth in a series of studies looking at the UK public's attitudes to science, scientists and science policy. It followed the *2000 Science and the Public*, *2004 Science in Society*, and *2008 Public Attitudes to Science* studies. A mixed methodology approach was used, which included a literature review of attitudes in the UK and internationally, a survey of 2 103 UK adults aged 16 and over, four sets of general public workshops and four general public discussion groups. The research was conducted by Ipsos MORI, in collaboration with the British Science Association (BSA), on behalf of the BIS. It was based on the BIS definition of science, and therefore explored attitudes not only to science, technology, engineering and mathematics (STEM) subjects, but also to research more broadly (e.g. including research into the social sciences). The study focused on: how people see science, finding out about science, trust in science, regulating science, public consultation and involvement in science, and various aspects of science in people's lives.

The fifth in the series of studies, Public Attitudes to Science 2014 (Castell et al., 2014) incorporated similar research, but was also expanded to include attitudes to big data, agri-science and food security, robots and emerging energy technologies. As with the previous PAS studies, the development of the survey was overseen by a steering group, consisting of individuals from government departments and other public bodies, academics, scientific bodies and industry associations. The study adopted a mixed methods approach, including:

- A representative face-to-face survey of 1 749 UK adults aged 16+ using a probability sampling approach;
- A booster face-to-face survey of 315 16–24 year-olds using a quota sampling approach;
- Social listening to explore how people find out about and discuss science online;

- Four waves of online qualitative research with members of the Ipsos MORI Connects online community to further explore the attitudes and behaviours of those who are already online;
- Eight follow-up face-to-face observational interviews with members of the online community, observing how they sought out science-related information online; and
- A Day of Discovery workshop with 106 members of the general public in London to further explore issues raised by the survey data.

Data from the main 2014 survey was weighted to be representative of the UK adult population, and data from the booster survey were combined with the main survey to create an overall dataset of 510 16–24 year-olds. This was then weighted to represent the UK 16–24 age group profile. For the first time, PAS 2014 moved the main survey from quota sampling to a probability sampling approach, in order to ensure that the findings were as robust as possible, and to give added assurance of their reliability to those who use the data. Table 5 presents the subject areas included, and some of the findings from PAS 2014.

Table 5: Areas assessed in Public Attitudes to Science 2014 (UK)

Subject area	Summary	Examples of findings
How people see science, scientists and engineers	• Hopes and concerns • Science and religion • Attitudes to specific topics • Scientists and engineers	81% agreed that science will make people's lives easier; 55% thought that the benefits of science outweigh any harmful effects. 9/10 thought that scientists (90%) and engineers (88%) make a valuable contribution to society.
Finding out about science	• Interest • Sources of information • Feeling informed • Confidence in finding out about science	84% agreed that science is such a big part of our lives that we should all take an interest. More than half (55%) did not feel informed about science, and scientific research and developments.
Discussing science in a digital age	• How do people discuss and share science stories online?	Peaks in online conversation tended to follow key offline events, press releases or public announcements.
Trust and confidence in science	• Trust in information, media reporting, scientists • Awareness of, and confidence in regulation	71% felt that the media sensationalises science.
Public involvement in science	• Do people want to be involved? • Government involves the public? • Scientists communicate with the public? • Early communication	69% thought that scientists should listen more to ordinary people. 75% felt that Government should act in line with public concerns about science.
Science in people's lives	• Science as a leisure or cultural activity • Studying science • Careers in science and engineering	67% had been to at least one of the science-related leisure or cultural activities asked about in the previous year. 51% thought the science they learnt at school had been useful in their everyday lives. 73% found jobs in science interesting, compared to 68% for engineering jobs.
Science and the economy	• Science funding • Economic benefits	65% disagreed that science funding should be cut because the money can be better spent elsewhere. 76% felt that scientific research makes a direct contribution to economic growth.
Attitudes to specific STEM topics	• Big data • Agri-science and food security • Robots • Emerging energy technologies	60% thought ensuring that there was enough food to go around is at least a fairly big issue in the UK. 42% agreed that the Government was working hard to ensure that people in the UK would have enough fuel for future needs. People were largely supportive of off-shore wind farms (76%), but less so when it came to carbon capture and storage (51%) or fracking (36%).

Adapted from Castell et al. (2014)

PAS 2014 findings were compared to those in previous studies, where possible, in order to examine trends in attitudes over time. PAS 2014 also included questions from two earlier surveys: the 1996 British Social Attitudes Survey, and the 1988 Public Understanding of Science Survey, so trends could be observed over a longer period. These data would play an important role in informing policies, strategies and programmes around science and the public. The studies have been used by the Department for Business, Innovation and Skills as one of the main ways to assess the achievements of the Charter for Science and Society (Castell et al., 2014). PAS 2014 also incorporated a study blog, which played a role in the dissemination of the research findings, and enabled scientists and science communicators to comment on the study while it was taking place (Castell et al., 2014).

Wellcome Trust Monitor

In addition, three waves of the *Wellcome Trust Monitor* have been conducted, tracking variations of public views on science, biomedical research and science education in 2009, 2012 and 2015. In 2009, 1 179 adults aged 18+ and 374 young people aged 14–18 were surveyed (National Centre for Social Research, 2009); in 2012, 396 adults aged 18 and over, and 460 young people aged 14–18 were included (Ipsos MORI, 2013); and in 2015, 1 524 adults were involved in the study (Ipsos MORI, 2016). These studies have focused on areas such as exposure to science; awareness and understanding of science and medical research; participation in, and engagement with, science and medical research; information sources; support, expectations and concerns; attitudes, experiences and perceptions of science education, and attitudes towards science as a career.

The various surveys which have been conducted on the public and science in the UK provide valuable information related to a range of S&T issues. The frequency with which the information is provided by the various studies also allows for ongoing assessment of the public relationship with science.

4.5 China National Survey of Public Scientific Literacy

The China Research Institute for Science Popularization (CRISP), a non-profit organisation, was established under the approval of the State Council in 1980. The proposal for such an institute was initiated by Mr. Gao Shiqi, a well-known Chinese scientist and science writer. Subordinate to the China Association for Science and Technology, CRISP is as a unique national institution focusing on studies related to science and technology communication (CRISP, n.d.).

CRISP pursues its goal in the interest of the public good, and its main objectives focus on theoretical and applicable research in relation to science popularisation, as well as parallel studies of equal concern between China and other countries. Recently, CRISP has been undertaking more than 40 research projects each year and developing collaborative relationships with a range of research organisations in other countries (CRISP, n.d.). One of the projects undertaken by CRISP focuses on the analysis of public scientific literacy. In 2018, CRISP conducted the 10th Civic Scientific Literacy Survey in order to further promote the effective implementation of the Action Plan Outline for Improving People's Scientific Literacy (2006–2010–2020) and to track the mid-term status of the goals set out in the national and local 13th Five-Year Plans for the Promotion of Civic Scientific Literacy (CRISP, 2018).

The 2018 survey was conducted by the National Bureau of Statistics (NBS), and targeted adult citizens aged between 18 and 69. The whole country and all provincial levels were set as population and sub-population respectively for sampling. The realised sample included 60 177 respondents. Tablets were used to carry out face-to-face interviews (CRISP, 2018). The following table provides the subject areas covered, and some of the findings.

Table 6: China National Survey of Public Scientific Literacy (2018)

Subject areas	Example of findings
Civic scientific literacy	8.47% of citizens qualified as scientifically literate, compared to 6.20% in 2015.
Main sources of S&T information (every day)	The most popular sources of S&T information were TV (69%), followed by the Internet (65%), friends/relatives/colleagues (38%), radio (24%), newspapers (10%), books (8%) and periodicals (6%).
Most popular Internet sources	Four most popular: WeChat (96%), portal websites such as tencent.com (83%), search engines such as baidu.com (80%) and specialised websites such as guokr.com (68%).
Visits to S&T venues in the preceding year	Five most popular S&T venues: Zoos, aquariums or botanical gardens (58%), public libraries (47%), reading rooms (43%), industrial and agricultural park (32%), and S&T museums and other S&T venues (32%).
Participation in science popularisation activities in the preceding year	Citizens participated in S&T exhibitions (22%), popular science lectures (19%), S&T training (17%), S&T Week, S&T Festival and Science Day (15%) and S&T consultation (14%).
Interest in S&T news topics	Interest: new scientific discoveries (77%), new inventions and new technologies (76%), new advances in medical science (73%).
Interest in S&T related information	Environmental pollution and governance (85%), computer and network technologies (69%), new energy development and utilisation (67%), universe and space exploration (56%), genetics and transgenic technology (56%), nanotechnology and new materials (50%).
Attitudes towards S&T	77% agreed that 'the public's understanding of and support for STI lay the foundation for accelerating the building of China into an innovative nation'. 77% agreed that 'the government should provide more approaches for the public, like hearings and so on, in order to promote public participation in S&T decision-making'.
Prestige and reference of S&T profession	Among the 11 professions listed, physicians (52%), scientists (49%), and engineers (25%) ranked in the top five.
Interest in cutting-edge S&T information	Respondents were 'very' or 'moderately' interested in new generation information technology (91%), new energy technology (90%), intelligent manufacturing (84%), life science and technology (84%) and new material technology (79%).
Attitudes towards AI	91% agreed that 'the development of AI will help boost human productivity and bring great convenience to people's lives'. 79% agreed that 'the development of AI might give rise to a large number of unemployed people, but at the same time it will create new employment opportunities'.

Adapted from CRISP (2018)

The surveys have helped obtain trend data, showcasing the development status of civic scientific literacy at national and provincial levels in China, as well as S&T information sources, public engagement in science popularisation activities, and public attitudes towards S&T since the beginning of the 13th Five-Year Plan period (CRISP, 2018).

4.6 Sweden's VA (Vetenskap & Allmänhet) Barometer

Vetenskap & Allmänhet (VA) (Public and Science) is a Swedish non-profit membership organisation founded in 2002. The VA Sweden aims to promote dialogue and openness between researchers and the public (Vetenskap & Allmänhet, n.d.), with the belief that dialogue is a cornerstone of a democratic society and key to solving societal challenges. VA Sweden's members consist of some 90 organisations, authorities, universities, companies and associations, as well as a number of individual members. The organisation is funded through membership fees, project grants and a grant from the Swedish Ministry of Education and Research. The main goals of the VA Sweden are to 1) ensure that the public understands what science is, how research works, and its role in society; 2) provide those working in education and research with knowledge about: public attitudes to research, the importance of dialogue and engagement with society, and methods for science communication; 3) ensure that decision makers have access to science and recognise the value of dialogue and collaboration between researchers and society at large, and act accordingly; 4) strengthen VA Sweden's role as an expert organisation in dialogue, science communication and public engagement both nationally and internationally; and 5) ensure that VA Sweden's members represent a broad range of societal actors. One of the strategies employed to achieve these goals is knowledge development, through conducting studies and surveys to gain knowledge about the relationships between science and society (Vetenskap & Allmänhet, n.d.).

This strategy includes an annual VA Barometer that explores the Swedish public's attitudes towards science, including interest, confidence, attitudes to research, research as a career, science and society, technology, and personal involvement in science. The survey is conducted using telephonic interviews using a stratified random sample of approximately 1000 respondents aged between 16 and 74 each year. The interviews are conducted each year over a two-week period during September and October (Vetenskap and Allmänhet, 2018). The 2018/2019 VA Barometer, which was the seventeenth survey, included 1 052 telephone interviews with a representative sample of the Swedish population. The respondents were representative in terms of gender, age and place of residence, and the results were weighted retrospectively to ensure representativeness in relation to levels of education. Table 7 provides an overview of the subject areas addressed, as well as some of the findings from the 2018/2019 survey.

Table 7: Areas assessed in Sweden's VA Barometer (2018/2019)

Subject area	Summary	Examples of findings
Confidence	• Confidence in researchers and research	75% had a 'very high' or 'fairly high' confidence in research. 84% indicated confidence in researchers at universities and 58% for researchers working in companies.
Attitudes towards science	• Scientific and technological development	78% felt that scientific and technological developments have made life 'a lot' or 'somewhat better' for ordinary people.
Science and politics	• Research as election priority/ public debate • Role of science in politics	43% believed that science has 'too weak' an influence on politics. Many indicated that they felt that business (31%) and politics (35%) have 'too strong' an influence on science.
Public and research	• Public involvement • Personal involvement • Type of involvement	73% felt that it is 'fairly important' or 'very important' for the public to be involved. 32% indicated that they would consider participating in research themselves.
Research as a career	• A career as a researcher?	Half of 16- to 29-year-olds (50%) said they would not like to work as researchers in the future.

Adapted from Vetenskap & Allmänhet (2018)

The VA Barometer focused predominantly on research (confidence in researchers and research, public involvement in research, research as a career); science and politics; and scientific and technological developments. The findings provide an overview of the role of science and technology in society, particularly through research. Sweden is another country which has high educational attainment levels: in 2017, 83% of 25 to 64 years old had completed secondary school and 42% had attained a post-secondary degree (National Center for Education Statistics, 2019).

The VA Barometer produces knowledge on the relationship between the public (society) and science, thereby playing a role in enhancing dialogue around science issues between researchers and the public. The results of the VA Barometer 2019/20 are now available.

4.7 India Science Report

The Indian Government aimed to move the country towards a knowledge-based economy. In 2004, India's National Council of Applied Economic Research (NCAER) commissioned a national study that sought to assess India's preparedness to overcome challenges and to take advantage of opportunities that a knowledge-based economy would bring. The survey was administered face-to-face to over 30 000 members of the public over the age of ten years, using random stratified sampling. The survey aimed to take stock of the science and engineering human resources that the country possessed, and assess how these resources were distributed both by type of profession and geographic location. One component of the survey focused on public attitudes toward S&T. This included questions related to public sources of S&T information, interest in S&T issues, and knowledge of S&T. From this they produced the India Science Report: Science Education, Human Resources and Public Attitude towards Science and Technology (National Council of Applied Economic Research, 2005).

The first Prime Minister of India, Pandit Jawaharlal Nehru, introduced the concept of modern scientific temper. India embraced the concept of 'scientific temper', which was used to describe a spirit of enquiry among people that would lead to a rational manner of thinking. The Constitution of India makes special provision to develop the scientific temper, humanism and the spirit of enquiry and reform (Patairiya, 2016).

It is interesting to note that levels of scientific literacy were not assessed in the survey which instead focuses on gaining insight into the contextual factors that impact on S&T academic achievement and on career choices. Such results provide a more holistic image of how the relationship between the public (learners in particular) and S&T is constructed. By surveying the general public and learners separately, the study recognises the different sectors within the public, or, in terms of the framework proposed for South Africa, the different publics. It also recognises that the public–S&T relationship is different for each sector of the public. This allows for measurement that is relevant to that particular section of the public. Also, by exploring the contextual factors that influence the relationship, this study acknowledges that S&T is situated within society. This is in line with the Science in Society framework. (For more information and findings from the India Science Report, see Reddy et al., 2009).

4.8 Public Awareness of Science, Technology and Innovation (STI) Malaysia

In line with efforts towards greater scientific literacy, the Malaysian Government through the Malaysian Science and Technology Information Centre (MASTIC) has monitored the public's awareness of science and technology, conducting a study every two years between 1994 and 2004 on the Public Awareness of Science, Technology and Innovation (STI). The survey was undertaken again in 2008 and 2014. The findings of this study are important in terms of assisting policy makers to plan and implement appropriate strategies to ensure that science, technology and innovation (STI) are better understood and more appealing to civil society in the country (MASTIC, n.d.). The 2014 study highlighted the importance of understanding the public's awareness and knowledge of STI in planning efforts to reach their development goal of becoming a high-income and knowledge-based economy. There is a belief in the country that STI is the basis upon which Malaysia can compete in an increasingly globalised and technology-driven world. To reach that goal, the report indicated that a number of programmes, policies and plans were being formulated. An important component of the development goal was noted as promoting a scientifically literate society, as a means of improving peoples' capacity to make the best use of S&T in their lives, and have a better understanding of the world around them. Scientifically literate citizens would be able to follow science news and participate in science-related policy matters. Continuous learning would thus be promoted (Ministry of Science, Technology and Innovation Malaysia, 2014).

The various surveys addressed interest in, and awareness of, science, various knowledge and attitude items and visits to informal science institutions. The survey uses face-to-face interviews as a data- collection tool, and the interviews are completed by enumerators. The 2014 study used a probability sampling approach to estimate the public awareness levels of STI in Malaysia. A representative sample of the Malaysian population was drawn from the household frame maintained by the Department of Statistics Malaysia (DOSM). Visits were made to 1 500 households, selected randomly across Malaysia's 13 states and three Federal Territories, and face-to-face interviews were conducted. After deducting the non-valid and ineligible cases, a total of 1 103 households were considered as valid units, and the interviews yielded a sample of 2 653 respondents. The final sample included Malaysians aged between 12 and 64 (Ministry of Science, Technology and Innovation Malaysia, 2014). The table below presents the subject areas covered and examples of some of the findings of the 2014 survey.

Table 8: Areas assessed in Public Awareness of STI Malaysia (2014)

Subject area	Summary	Examples of findings
Public Interest in STI	• Interest	78% were interested in STI.
Knowledge of STI	• Understanding of STI Terms and Concept • Pseudoscience	46% were able to correctly answer factual knowledge questions.
Public Attitudes towards STI	• Scientific Research • STI, Scientific Research and Science • Impact of STI • Low Science Stream Enrolment • Specific STI Issues	53% felt that scientific research was more beneficial than harmful; 92% agreed that 'Science, Technology and Innovation improve the quality of our lives'; 95% acknowledged the importance of STI for the progress of the nation; and 88% recognised that they need scientific knowledge in order to manage their daily lives better.
Information Sources and Involvement	• Sources of Information through Media • Internet Usage • STI-related Places	Most common sources of information on STI were television (89%), print newspapers (63%), internet (53%), radio (43%), books (39%) and print magazines (24%).
Public Awareness of STI-related Government Programmes and Policies	• Awareness of Government STI Programmes • Awareness of National STI related Policies • Views on Government Spending	At least one in four respondents had heard of STI- related government programmes.

Adapted from Ministry of Science, Technology and Innovation Malaysia (2014).

The 2014 Malaysian study surveyed 12- to 64-year-olds, allowing for an understanding of public attitudes in a range of age groups. In terms of knowledge, the youth group (51%) had a higher percentage of correct answers than the adult (46%) and children's groups (36%). The youth group had on average the highest interest in STI issues at 79.5%, followed by the adult group at 76.8% and the children's group at 63.7%. In terms of sources of information, usage rates for newspapers were 82% for children, 88% for the youth group and 90% for adults. In contrast, the television usage was the highest for the children's group (99%), in comparison to the youth (98%) and the adults (97%), although only by a small margin.

These studies have provided the Government with key indicators to assess the Malaysian public's engagement, attitudes and levels of exposure to STI issues. They have also provided recommendations, and helped the Government to plan programmes and long-term projects to increase the levels of STI knowledge and learning among Malaysians (Ministry of Science, Technology and Innovation Malaysia, 2014). MASTIC will be conducting Public Awareness of Science, Technology and Innovation Malaysia 2019 and the results are expected to be released by October 2020 (MASTIC, n.d.).

4.9 3M State of Science Index Global Report

3M is a Global Fortune 500 corporation, with operations in 70 countries, including South Africa, that is committed to developing technology and products that advance companies, enhance homes and improve life. Sustainability is a core value of the company, and 3M has been involved in addressing sustainability issues since the 1975 establishment of their Pollution Prevention Pays programme, with their involvement also embraced in their 2025 Sustainability Goals and Sustainability Value Commitment. 3M is committed to a science-based, collaborative approach to solving shared global challenges and improving lives (3M SA, n.d.; 3M USA, n.d.a).

3M recognised that in order to understand the public's views about science they needed to conduct their own research. The State of Science Index undertaken by 3M in 2018 and 2019 explores global attitudes to science. The survey was commissioned across 14 countries to examine perceptions of science and its impact on society. The survey also attempts to capture sentiment towards science, through measures of appreciation, popularity, interest level and trust vs. scepticism.

Approximately 14 000 adults in 14 developed and emerging countries around the world, including South Africa, were targeted each year. Representative samples of adults aged 18 and over in each country were drawn, based on age, gender, region, and race/ethnicity (where applicable). Data were collected using 15-minute surveys, offline and online. In 2018, a sub-set of 345 key business decision influencers (globally) was also included. These influencers were selected based on the following criteria: being between the ages of 25 and 54; high-income earners (US$100 000+ and equivalent globally); and at least partially responsible for the purchasing decisions for their company's products, services or solutions. In addition, they had to be employed in at least one of the following core industries: transportation or cars/auto parts; electrical equipment, repair & supplies; healthcare; manufacturing; energy; or safety/industrial hygiene (3M, 2018).

In both years, the countries surveyed included Canada, Germany, Japan, Singapore, UK, US, Brazil, China, India, Mexico, Poland and South Africa. In 2018, France and Saudi Arabia were included, and in 2019 the sample incorporated South Korea and Spain (3M, 2019).

In 2018, across the countries, four in ten (42%) respondents believed that their country was falling behind others in relation to scientific advancements. In South Africa, the percentage increased to 61%. Around 80% of respondents (82%) stated that they would encourage children to pursue a career in science, increasing to 89% in South Africa. The Science Trust Index quantifies perceptions of trust and scepticism of science in each country: the higher the score, the greater the level of trust in science. South Africa's trust index was found to be 51.1, compared to the 14-country total of 55.1 (3M, 2018). The following table highlights the subject areas covered in the 2019 report, and some of the findings, including some findings from South Africa.

Table 9: Areas assessed in 2019 3M State of Science Index Global Report

Subject area	Summary	Examples of findings	Examples of South African findings
Image of science	• Scientific knowledge • Confidence • Interest • STEM careers and skills	88% believed it is important for everyone to have basic scientific knowledge, but 57% were not confident in their science knowledge.	It is important for everyone to have basic scientific knowledge: 87%; 54% were not confident in their science knowledge.
		72% were curious about science, as opposed to indifferent (18%) or intimidated (10%).	67% were curious, 19% were indifferent and 14% were intimidated.
		The top driver of science interest was the belief that advancements will benefit future generations (59%).	51% believed that advancements will benefit future generations.
Impact of science	• Sources of scientific information • Views of scientists • Communication • Interaction (human vs. artificial/virtual) • Future innovations/ scientific advancements	Most felt that scientists should be sharing results in easy to understand language (88%), and in a way more relatable to people's everyday lives (84%).	Scientists should be sharing results in easy to understand language (88%), and in a way more relatable to people's everyday lives (85%).
		Top sources from which people believe science information: people who work in scientific fields (80%), documentaries (77%), friends or family (61%), their regular news outlets (60%).	Documentaries (75%), people who work in scientific fields (72%), their regular news outlets (59%), friends or family (51%).
		Respondents were more *afraid* than excited about human cloning (77%), genetically modified foods (69%), gene editing (65%), and robots in every workplace (52%). In contrast, they were more *excited* than afraid of vaccines for chronic diseases (87%), space travel/ tourism (71%), flying cars (57%) and driverless cars (53%).	More *afraid*: Human cloning (70%), GM foods (63%), gene editing (58%), robots in every workplace (57%), More *excited*: Vaccines for chronic diseases (83%), space travel/tourism (74%), driverless cars (58%), flying cars (56%).
Expectations of science	• Role of science in solving global problems • Top issues for science to solve • Scientific advancements • Trust in science • Responsibility for science funding and innovation • Appreciation of science	86% were optimistic about the role of science over the next 20 years, and 63% believed: 'The best days of science are still to come'.	81% said it made them feel more optimistic than pessimistic; 'The best days of science are still to come': 61%.
		35% were sceptical of science.	Sceptical of science: 45%.
		61% felt their government should shoulder the weight of funding science and science-based innovation.	75% felt their government should the most responsible for funding.
		91% felt that science is important to society in general, versus 86% to their family in their everyday lives.	Science is important to society in general: 85%; 81% to their family in their everyday lives.
		27% did not see the point of needing to understand science as an adult, whereas 23% said they found science boring.	'As an adult, I don't see the point of now needing to understand science': 26%; 'Science is boring': 23%.

Adapted from 3M (2019) and 3M US (n.d.b)

The 3M survey provides important information regarding the public's attitudes to various aspects of science in a range of countries around the world. The website also allows all interested parties to explore the survey data, which can be disaggregated according to various categories, including by country, age group, gender, income, industry, type of employment, geographic location (urban/rural), and whether the respondents were parents or not. The website provides an interactive platform for the exploration of the data collected.

4.10 Relevance of Science Education (ROSE)

The *Relevance of Science Education* (ROSE) study is an international comparative study of emotional and attitudinal issues that affect the learning of S&T among learners aged 15 to 16. ROSE is supported by the Research Council of Norway and, the Ministry of Education in Norway, the University of Oslo and the Norwegian Centre for Science Education. Key international research institutions and individuals work jointly on the development of theoretical perspectives, research instruments, data collection and analysis (University of Oslo, 2016). Approximately 40 countries take part in ROSE (University of Oslo, 2016).

In many countries, science education is an important element of schooling, and is increasingly taught from the earlier years of schooling. High quality S&T education is seen as important training for citizenship as well as for preparation for work in a world dominated by new technologies and competitive knowledge-based industries (Schreiner and Sjøberg, 2004). The ROSE study is based on the notion that S&T are important aspects of life, regardless of culture and level of material development. It is therefore necessary for the S&T curriculum to be adapted to the needs of learners, which may vary between countries, and between groups of learners in each country. Furthermore, more weight should be given to the voice and views of learners when developing curricula and implementing pedagogy (Schreiner and Sjøberg, 2004).

Unlike studies such as TIMSS and PISA, ROSE focuses on the attitudinal and motivational aspects of S&T, rather than testing the understanding of science content. The focus is on aspects that may be important in relation to how learners engage with and relate to S&T in schools, and in everyday life. The research instrument is a questionnaire mostly consisting of closed questions with four-point Likert scales (ROSE, n.d.a). The ROSE instruments gather and analyse information related to learners' prior experiences with and views on school science, their S&T-related out of school experiences, their interest in different S&T-related content in different contexts, and their views and attitudes towards S&T and scientists in society. It also aims to understand their hopes, plans and aspirations for the future (ROSE, n.d.a; Schreiner and Sjøberg, 2004; Sjøberg and Schreiner, 2019; University of Oslo, 2016).

While affective aspects, such as interest, attitudes, appreciation for S&T, motivation and engagement are important as a means to recruit more people into S&T, they are also important factors on their own. Furthermore, the attitudinal outcomes of involvement in a school subject likely form a longer lasting memory than the content that is covered. These aspects are, however, not often measured through exams or large-scale comparative studies (Schreiner and Sjøberg, 2004). The study therefore aims to provide empirical evidence and to stimulate informed discussions about priorities and alternatives in S&T education, ways to improve curricula and enhance interest in S&T (Schreiner and Sjøberg, 2004; University of Oslo, n.d.).

ROSE built on the project Science and Scientists (SAS) that involved approximately 9 300 13-year- old learners. The ROSE study built on the experiences, results and wide network of partners that were involved in SAS (Schreiner and Sjøberg, 2004; Sjøberg and Schreiner, 2019). In the ROSE study, the target population shifted from 13-year-olds to 15-year-olds. This was done because of the recognition that learners are more mature at the age of 15 and are therefore likely to have reflected more on their interests, priorities and attitudes to and comprehensions of science-related issues and schooling, as well as have an idea of their future plans.

They are also more likely to give more consistent responses to the questions, enhancing the reliability of the data. In addition, this is the age when learners in most countries reach the end of compulsory schooling; and when educational and curricular choices for the rest of their school career are made (Schreiner and Sjøberg, 2004; Sjøberg and Schreiner, 2019).

South Africa collected data in the Western Cape and KwaZulu-Natal. Unfortunately the results of the study have not been published.

Table 10 presents the areas assessed in ROSE[18].

Table 10: Areas assessed in the ROSE questionnaire

Areas assessed	Summary
Areas that learners want to learn about (STEM)	• Interests and purpose of S&T education
S&T careers	• Potential future occupation or job
Learners and environmental challenges	• Attitudes towards environmental challenges
Science at school	• Experiences of S&T education in the classroom • Impact of S&T education
Science and technology in society	• Attitudes towards S&T issues
Out of school S&T experiences	• Practical experiences of S&T in everyday life
'Myself' as a scientist	• S&T issues that the respondents find interesting and important and would like to research

Adapted from ROSE (n.d.b)

The ROSE study aims to stimulate research cooperation and networking so that participants can learn from each other (University of Oslo, 2016). Several hundred academics around the world have been involved in the ROSE project, and many of them continue to work together in this network of researchers and teacher trainers (Sjøberg and Schreiner, 2019). The participants have been able to meet at conferences, and special ROSE workshops have been hosted in different countries (University of Oslo, 2016).

The ROSE results have been presented at various meetings and events (Sjøberg and Schreiner, 2019). Furthermore, students, teachers and researchers around the world continue to seek permission to use the ROSE instrument, or parts of it, in their research. The instrument, or parts of it, is also used in teacher training in some countries (Sjøberg and Schreiner, 2019).

4.11 Programme for International Student Assessment

The Programme for International Student Assessment (PISA) is a cyclical study that is conducted every three years, with the first study taking place in 2000. PISA is coordinated by the Organisation for Economic Co-operation and Development (OECD), and emphasises functional skills that learners have acquired as they near the end of compulsory schooling. Each round of PISA assesses approximately 500 000 15-year-olds across countries, using paper-based or computer based assessments. The study includes three core domains: reading, mathematics and science, one of which is tested in detail in each round. With the alternating

18 These reports provide findings form the ROSE study: Jenkins and Pell (2006); Jidesjö et al.. (2009); Matthews (2007); and Sjøberg and Schreiner (2019).

schedule of domains, a thorough analysis of achievement in each of the three core areas is conducted every nine years (OECD, 2018a). The following table shows the years in which each of the three domains was, or will be, the core domain.

Table 11: Years each core domain assessed in PISA

Core Domain	Years
Reading Literacy	2000, 2009, 2018
Science Literacy	2006, 2015, 2024
Maths Literacy	2003, 2012, 2021

Within PISA, science literacy is defined as the ability to engage with science-related issues, and with the ideas of science. In order to answer the questions successfully, learners must be able to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically. Mathematical literacy is defined as learners' capacity to formulate, employ and interpret mathematics in a variety of contexts. Learners must be able to reason mathematically and use mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena (OECD, 2018a).

The survey assesses the extent to which learners near the end of compulsory education have acquired key knowledge and skills that are essential for full participation in modern societies. The assessment does not focus only on whether learners can reproduce knowledge but also examines how well they can extrapolate from what they have learned and apply that knowledge in unfamiliar settings, at school and outside school (OECD, 2018a). In 2018, 79 countries took part in PISA, including all 37 OECD member countries (Education Counts, n.d.). The core domain of the study was reading literacy.

The PISA 2015 survey focused on science, with reading, mathematics and collaborative problem solving as minor areas of assessment. PISA 2015 also included an assessment of young people's financial literacy, which was optional. Approximately 540 000 learners in 72 participating countries and economies, completed the assessment in 2015, representing about 29 million 15-year-olds across the participating countries and economies (OECD, 2018b). The study used computer-based tests, with a mixture of multiple-choice questions and open-ended questions. Learners also answered a background questionnaire, related to themselves, their homes, and their school and learning experiences. School principals completed a questionnaire that covered the school system and the learning environment. For additional information, some countries/economies distributed a questionnaire to teachers, and some distributed questionnaires to parents (OECD, 2018b). Learners were asked questions about out-of-school S&T-related experiences; interests in learning different S&T topics; prior experiences with and views on school science; views and attitudes to science and scientists in society; and future hopes, and their priorities and aspirations. The subject areas and examples of findings from the survey are summarised in the following table.

Table 12: Areas assessed in PISA (2015)

Areas assessed	Summary	Examples of findings
Epistemic beliefs about science	Beliefs about the nature of knowledge of science, and the validity of scientific methods of enquiry as a source of knowing	Agreement with the following statements: • A good way to know if something is true is to do an experiment (84%). • Ideas in <broad science> sometimes change (81%). • Good answers are based on evidence from many different experiments (86%). • It is good to try experiments more than once to make sure of your findings (85%). • Sometimes <broad science> scientists change their minds about what is true in science (80%). • The ideas in <broad science> science books sometimes change (79%).
Science engagement	Science career expectations	24% reported that they expect to work in an occupation that requires science training beyond compulsory education.
	Science activities	The most common science-related activities were watching TV programmes about science (23%), and visiting websites about science topics at least 'regularly' (19%).
Motivation for learning science	Enjoyment of science	On average, 66% of learners agreed that they enjoy acquiring new science knowledge, and 64% were interested in learning about science.
	Interest in broad science topics	Interest: 'how science can help us prevent disease' (66%), energy and its transformation (49%), 'the universe and its history' (66%), 'energy and its transformation' (49%), and motion and forces (46%), and in topics related to the biosphere (41%).
	Instrumental motivation for learning science	On average, 69% agreed that making an effort in school science subjects is worthwhile as it will help them in their future work, 67% agreed that studying science at school is worthwhile as it will improve their career prospects.
Science self-beliefs	Self-efficacy in science (perceived ability to use their knowledge of science in real-world situations)	Areas included 'Recognise the science question that underlies a newspaper report on a health issue', 'Describe the role of antibiotics in the treatment of disease', and 'Interpret the scientific information provided on the labelling of food items'. Most responses ranged from approximately 16% to 24%, with 'Explain why earthquakes occur more frequently in some areas than in others' at approximately 34%.

Adapted from OECD (2016)

PISA offers insights for education policy and practice, and helps monitor trends in learners' acquisition of knowledge and skills across countries, and by different demographic groups within countries (OECD, 2018b). PISA aims to help countries to incorporate the results of that learning into policy and practice. PISA has helped policy makers lower the cost of political action by backing difficult decisions with evidence, while raising the political cost of inaction by exposing unsatisfactory policy and practice (OECD, 2019).

4.12 Concluding Comments

The need to comprehend the public's understanding(s) of science has been recognised globally, and various countries have consequently conducted surveys to gain insight into this. Both developed and emerging countries have undertaken surveys related to S&T in general, as well as focusing on specific scientific topics which may have particular relevance and importance at certain points in time. The US and Europe have been at the forefront of such research, with multiple surveys being conducted at regular intervals. Other countries such as Brazil, China, Germany, Israel, Japan, Malaysia, Spain and Sweden have also undertaken surveys of the public understanding of science, some as once-off studies, and others as regular ongoing evaluation of public understanding.

Many of these studies are conducted in a particular country, whereas several are conducted across countries in specific continents, such as the Eurobarometer, or even across various continents, such as the Relevance of Science Education (ROSE) study. These surveys also provide an opportunity for comparison between countries and therefore an understanding of science attitudes among the public on a global scale. These attitudes also reflect the context of each country, thus affording greater insight.

Many of these surveys have been commissioned by government departments, based on the predominant S&T issues of concern in the country at the time. There are also some surveys that have been undertaken by the private sector, such as the 3M State of Science Index.

Some of these surveys focus predominantly on elements of scientific literacy, particularly those conducted earlier on; whereas the more recent surveys have incorporated elements of the public understanding of science and science in society approaches. This is evident in the questions included in the surveys, the methodologies used to conduct them, and the way data are presented. Many of the studies have used either only face-to-face interviews, or only telephone interviews as a means of data collection. There are, however, some studies which have begun to adopt a mixed methodology approach. These studies have used complementary data sources and incorporated qualitative methodologies, such as the analysis of media, social media, or one-on-one interviews, in addition to conducting quantitative public surveys.

The results from some of these surveys are presented on comprehensive websites that provide an enhanced level of interaction for users of the data. Some of these websites provide extensive data accessibility, statistical data, and opportunities for engagement with the data. For example, the 3M database provides an interactive space, where users can explore the data using a variety of disaggregations, such as age, gender, and occupation.

A review of the international surveys on the public relationship with science provides lessons that South African can use going forward in relation to the use of complementary methodologies, the types of questions to include in survey instruments, and the analysis and presentation of the data. All of these lessons are important to consider in enhancing the public relationship with science through broader science engagement.

5. SOUTH AFRICAN SURVEYS ON THE PUBLIC AND SCIENCE

5.1 Introduction

Since the early 1990s, South Africa has promoted the awareness and understanding of science and technology. Within this context, it has become increasingly important to measure public awareness, knowledge and attitudes to different aspects of science, and to ensure that the public is informed and able to participate in debates around science. Investigations of the South African public's relationship with science, including their attitudes towards S&T, their interest in S&T topics and their S&T related behaviour have largely been undertaken through public surveys. The first studies were conducted by the Foundation for Education, Science and Technology (FEST). One of the objectives of FEST was to 'initiate and support programmes strengthening the public understanding and appreciation of science and technology at all levels of society'. Thus FEST undertook a number of studies to measure 'appreciation and understanding'. In this chapter, we report on (i) the studies conducted by FEST; (ii) studies undertaken by the HSRC in its attitude surveys (EPOP, Omnibus Survey) which measured attitudes towards science and technology; (iii) surveys undertaken on specialised topics by the HSRC (SASAS); (iv) a study conducted by Laugksch on the scientific literacy of matriculants who entered tertiary institutions; (v) the development of indicators for the measurement of the South African publics' relationship with science by Parker (2017), (vi) attitudes to science and technology in the World Values Survey, (vii) the Afrobarometer, which included a South African study, and (viii) the Trends in International Mathematics and Science Study (TIMSS), which measures values and attitudes of Grade 5 and 9 learners. The World Values Survey and TIMSS are conducted in various countries around the world, however, country specific studies are conducted in South Africa.

Table 13: South African surveys conducted on the public relationship with science*

Title	Year
Pouris studies	
Understanding and appreciation of science among the public in South Africa (Pouris, FEST)	1991
Understanding and appreciation of science among South African teenagers (Pouris, FEST)	1993
Interests, Public Attitudes and Sources of Scientific Information in South Africa (Pouris, FEST)	2001
Assessing Public Support for Biotechnology in South Africa (Pouris)	2004
HSRC studies	
SA Science and Technology Indicators – Public Understanding of Science Chapter (FRD, HSRC)	1995
Public Understanding of Science in South Africa – aiming for better intervention strategies (HSRC, FRD)	1999
Omnibus Survey (HSRC)	1995
Evaluation of Public Opinion Programme (HSRC)	1999
SASAS Biotechnology (HSRC)	2003, 2015
SASAS Environment (HSRC)	2004, 2010, 2013
SASAS Climate Change/Global Warming (HSRC)	2007, 2017

Title	Year
SASAS Indigenous Knowledge (HSRC)	2009
SASAS Public Relationship with Science (HSRC)	2010, 2013
SASAS Energy (HSRC)	2011, 2012, 2013, 2017, 2018
SASAS Nuclear Energy/Technology (HSRC)	2011, 2013
SASAS Astronomy and SKA (HSRC)	2013
SASA Fourth Industrial Revolution (HSRC)	2018
PhD studies	
Development of indicators for the measurement of the South African publics' relationship with science (Parker)	2017
International studies with a focus on South Africa	
World Values Survey (World Values Survey Association, Stellenbosch University) (+/- 100 countries)	1981, 1990–1991, 1995–1996, 1999–2001, 2005–2006, 2010–2014, 2017–2020 (current)
Afrobarometer (Afrobarometer, Institute for Justice and Reconciliation, Plus 94) (34 African countries in most recent round)	1999–2001, 2002–2004, 2005–2006, 2008–2009, 2011–2013, 2014–2015, 2016–2018
Studies with a focus on learners/students	
The scientific and technological literacy of first-year physics students: the effects of a traditional school curriculum (Goolam)	2001
Test for Basic Scientific Literacy and its application in assessing scientific literacy of matriculants entering universities and technikons (Laugksch)	1996
Trends in International Mathematics and Science Study (HSRC, IEA) (Various countries worldwide)	1995, 1999, 2003, 2011, 2015, 2019

See Appendix B for a more detailed table.

5.2 Studies Conducted by FEST

In keeping with its objectives, the Foundation for Education, Science and Technology (FEST),[19] undertook a number of studies measuring the understanding and appreciation of science in South Africa. Three of the published studies included *Understanding and appreciation of science among the public in South Africa* (Pouris, 1991), *Understanding and appreciation of science among South African teenagers* (Pouris, 1993), and *Interests, public attitudes and sources of scientific information in South Africa* (Pouris, 2001).

Understanding and Appreciation of Science among the Public in South Africa

This study (Pouris, 1991) was the first attempt to study public literacy and attitudes towards S&T in South Africa and consisted of 1300 white (500 male, 800 female). Respondents were sampled using a random–suburb sampling technique among six suburbs in Cape Town, Durban, Johannesburg/Pretoria, Port Elizabeth, East London and Bloemfontein. The study used items from the National Science Foundation (1989) and Eurobarometer (1989) surveys to gauge public attitudes toward S&T. The survey included items to try to understand the public's knowledge of physics and earth sciences facts, beliefs about human origins, public attitudes towards astrology, and beliefs related to the effects of science in everyday life (For more information on this study, see Reddy et al., 2009).

19 FEST later became SAASTA.

Understanding and Appreciation of Science among South African Teenagers

In 1993, Pouris (1993) conducted a study among 13-year-old to 20-year-old South Africans, with 400 white and 400 black respondents surveyed in face-to-face interviews. A random sampling technique based on residential suburbs was used. Interviews were conducted in residential suburbs in Cape Town (8%), Durban (16%), Johannesburg/Pretoria (60%) and Bloemfontein (16%). The respondents were asked questions related to their knowledge, attitudes and beliefs regarding S&T. The items in this survey were again extracted from the NSF studies and the Eurobarometer (For more information on this study, see Reddy et al., 2009).

Interests, Public Attitudes and Sources of Scientific Information in South Africa

In 2000, FEST conducted a survey to assess levels of public understanding and appreciation of S&T. The specific objectives of the study were to: (i) identify the level of interest of the public in selected issues; (ii) examine public attitudes towards science and technology and (iii) analyse the sources of information used by citizens to improve and maintain their understanding of scientific and technological issues. This study (Pouris, 2001) was conducted in 1000 households in the metropolitan areas of Pretoria, East Rand, West Rand, Vaal, Port Elizabeth, Cape Town, Durban and Pietermaritzburg. The sample was chosen through a representative cluster-sampling approach, and face-to-face interviews were conducted. The demographic details of the sample were not stated in the study (For more information on this study, see Reddy et al., 2009).

5.3 Attitudinal surveys conducted by the HSRC

Omnibus surveys

The HSRC has conducted various surveys on the attitudes, beliefs, values and behaviour patterns of the South African public. Surveys of the public's attitudes towards various issues, which included items related to science and technology, were carried out in the Omnibus surveys from the 1980s until the late 1990s.

Evaluation of Public Opinion Programme (EPOP)

In 1999, the Omnibus survey was replaced by the Evaluation of Public Opinion Programme (EPOP), which was conducted annually among a nationally representative sample of the public. Modules within EPOP covered a wide range of public opinion topics. It was, however, criticised for the significant time lag between data collection and the dissemination of findings. In addition, the modules housed within EPOP were highly client-driven. The EPOP survey (1999) included items on (i) the importance of mathematics, science and technology in the lives of the South African public, (ii) public attitudes towards S&T measured through the set of items that constitute the Promise–Reservation index, and (iii) the balance between the benefits and harms of scientific research (For more information on this study, see Reddy et al., 2009).

South African Social Attitudes Survey (SASAS)

The predominant source of information regarding the public and science has been the Human Science Research Council's (HSRC) South African Social Attitudes Survey (SASAS), which was first undertaken in 2003, intending to be an upgrade of EPOP. SASAS is a nationally representative, repeated cross-sectional survey that gathers information about the country's changing institutions, its political and economic structures, and the attitudes, beliefs and behaviour patterns of its population. SASAS provides a long-term account of changes in the public's social, economic and political values in the country. Each round of SASAS is designed to produce a nationally representative sample of between 3500–7000 individuals aged 16 and older, in households that are spread across the nine provinces. The sample is drawn from the HSRC's Master Sample – a sampling frame that consists of 1 000 Population Census enumeration areas. Each SASAS round of interviewing consists of a sub-sample of 500 EAs drawn from the master sample, stratified by province, geographical sub-type and majority population group (HSRC, n.d.). The data is weighted to be representative of the adult public, benchmarked to the relevant mid-year estimates produced by Statistics South Africa.

Each round of SASAS incorporates a 'core' set of demographic, behavioural and attitudinal variables, for the purpose of monitoring change and continuity over time. In addition, each round accommodates rotating modules focused on specific themes, with the goal of providing attitudinal evidence which can inform policy and academic debate. Attempts are made to identify key perennial topics that would provide reliable and robust measures to shape our understanding of present-day South Africa and the processes of change within it (HSRC, n.d.). The SASAS has included a number of modules about the public's general relationship with science as well as specific modules on certain science topics. The table below provides an overview of the S&T modules which have been included in SASAS since 2003, the years in which each module was administered, and the topics covered in each module.

Table 14: SASAS Modules on Specific Science and Technology Topics

Module	Years	Focus
Biotechnology	2003 2015	Knowledge of biotechnology, genetic engineering, genetic modification, cloning, new technologies, uses of biotechnology, acceptance of biotechnology
Climate change/ global warming	2007 2017	Knowledge and concern of climate change, causes and results of climate change, responsibility for prevention, government involvement
Energy	2011 2012 2013 2017 2018	Household energy sources, energy expenditure, energy needs, electricity-quality and cost, ways to save energy, electricity provision
Environment	2004 2010 2013 2019[20]	State of the environment, pollution, genetic modification, governmental involvement, environmental issues, people vs environment, responsibility for protecting the environment, costs of environmental protection
Indigenous knowledge	2009	Opinion of indigenous knowledge, Government promotion of indigenous knowledge, roles in indigenous knowledge, sources of information
Public relationship with science	2010 2013	Promise reservation index, sources of information, science knowledge, science at school and as a career, interest in science and technology developments, science centres and museums
Nuclear energy/ technology	2011 2013	Knowledge of, benefits of, concerns about, uses of, risks of, role of nuclear energy in South Africa; role of government; sources of information
Public understanding of astronomy ad SKA	2013	Attitudes to astronomy, knowledge of and attitudes about the Square Kilometre Array Telescope (SKA)
4IR	2018	Promise reservation index, knowledge, skills, attitudes towards new technologies

BIOTECHNOLOGY

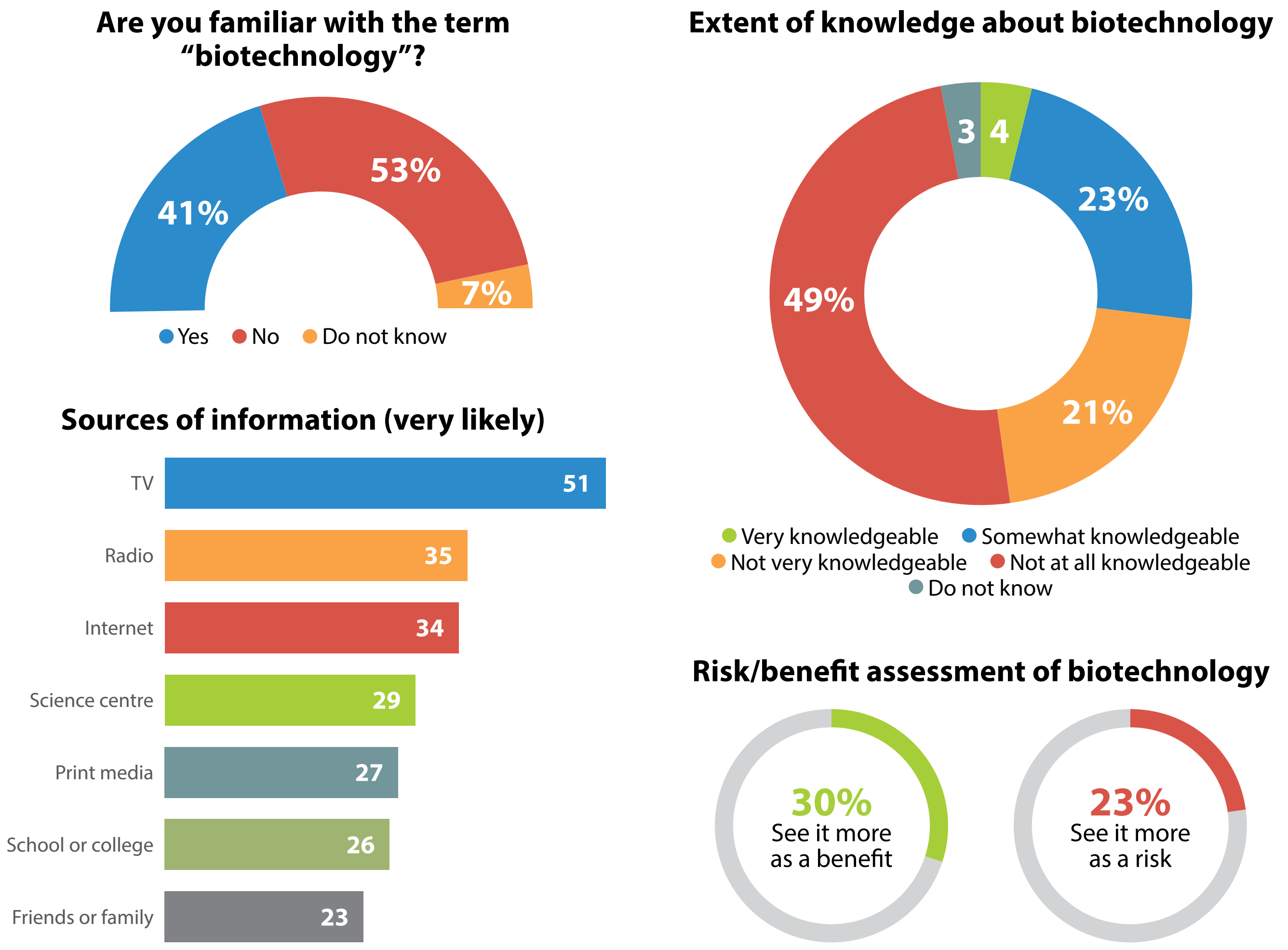
Biotechnology is seen as a critical domain of science and technology for the twenty first century. Its potential in the development and production of medicine, food, energy, and industrial processes is widely recognized (Gastrow, Reddy, Roberts and Ismail, 2016). In 2004, the DSI commissioned the HSRC to conduct a study on

20 The 2019 SASAS is being fielded in early 2020.

the public understanding of biotechnology in South Africa. A sample of 7 000 citizens over the age of 16 was realised across South Africa. Representivity of the sample was achieved through ensuring proportional representation of gender, age and race. Owing to a high portion of 'do not know' responses in the survey, it was difficult to adequately gauge attitudes towards biotechnology. The study did, however, illustrate the low levels of public knowledge about this topic and raised questions about the suitability of highly specialised sets of items or terms for a population with low levels of education.

A second module on biotechnology, commissioned by the Public Understanding of Biotechnology (PUB) programme of the South African Agency for Science and Technology Advancement (SAASTA), was included in the 2015 SASAS (Gastrow et al., 2016). Learning form the findings of the first module, items were carefully developed so as ensure that the questions were posed in such a way that they could be easily understood by even those people with a limited knowledge of biotechnology, and thereby minimise the percentage of 'do not know' responses. This allowed for a clearer picture of the South African public's understanding of the topic. The module included questions related to public attitudes towards science; biotechnology knowledge, access, and core concepts; a subjective knowledge assessment; and accessibility of knowledge. It also focused on perceptions of human evolution; genetically modified food (perceptions, knowledge, uses, attitudes); medical applications of biotechnology (perceptions, knowledge, attitudes); governance and institutions of biotechnology, biotechnology and indigenous knowledge systems; sources of information about biotechnology; and a general risk/benefit assessment of biotechnology. The figure below provides some key findings form the module, which was administered to 2 940 respondents.

Figure 2: Some results from SASAS on Biotechnology (2015)

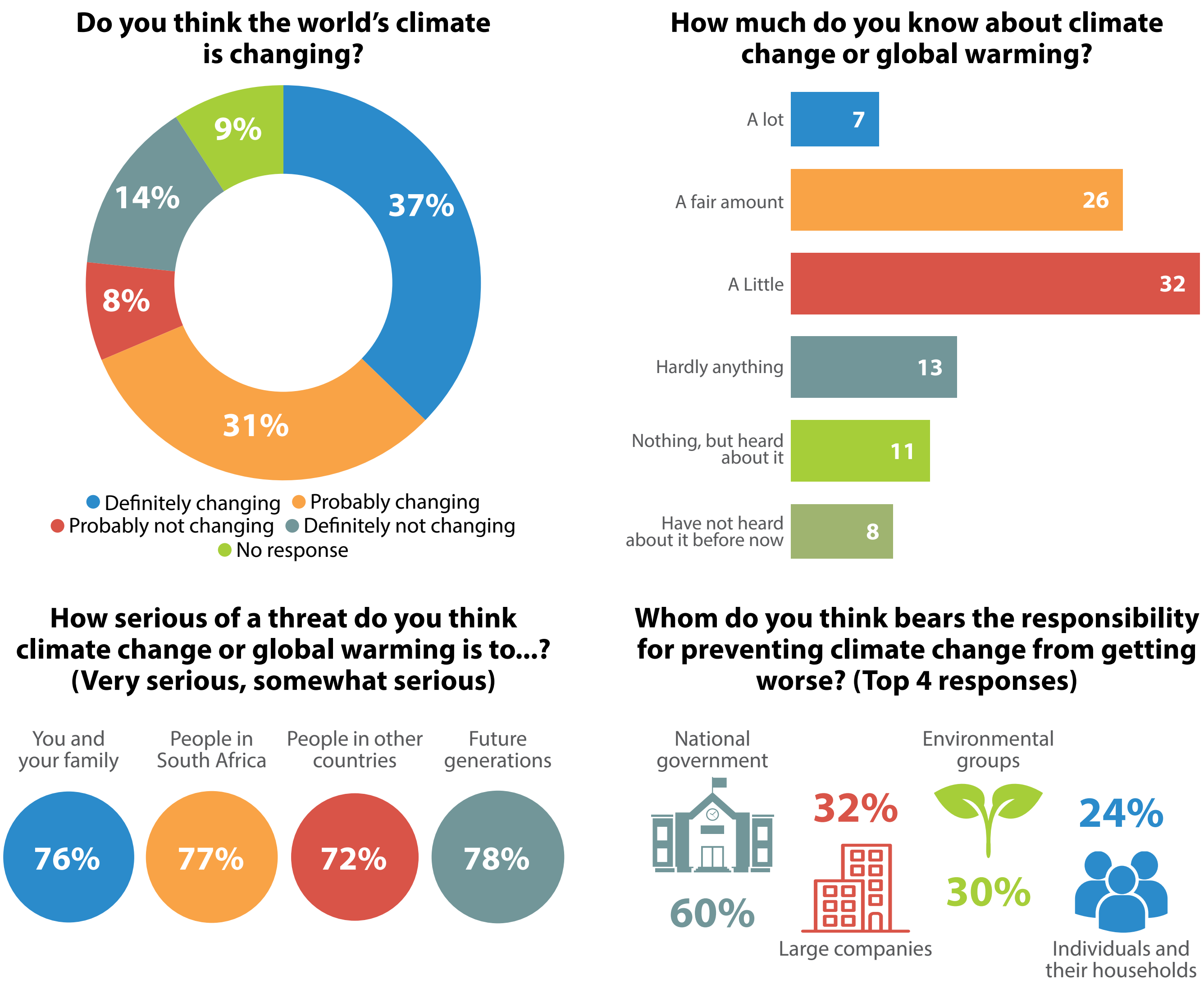


CLIMATE CHANGE/GLOBAL WARMING

Climate change is currently one of the most pressing issues across the globe. In South Africa, the 2012 National Development Plan (NDP) noted that South Africa is particularly vulnerable to the effects of climate change on health, livelihoods, water and food, with the poor being disproportionately affected (National Planning Commission, 2012). The vision for 2030 is stated in the NDP: 'By 2030, South Africa's transition to an environmentally sustainable, climate-change resilient, low-carbon economy and just society will be well under way' (National Planning Commission, 2012: 199). Responding effectively to both climate change mitigation and adaptation is therefore crucial. The 2019 White Paper on Science, Technology and Innovation (DST, 2019) highlights that climate change is one of the biggest risks facing nations, and that challenges of climate change will increasingly influence polices. In June 2018, a Draft National Climate Change Bill was published for public comment in Government Gazette 41689 (Notice No. 636) (RSA, 2018). The bill aims to develop an effective response to climate change and to ensure the long-term, just transition to a climate resilient and lower carbon economy and society.

In 2007, the HSRC was given ring-funding by the DSI (then the DST) for climate change research. The SASAS team suggested the inclusion of a module on climate change. The questions in the module included some verbatim from international modules, as well as some questions that were adapted to the South African context (Roberts, 2020, personal communication). In 2017, the SASAS team approached the DSI and proposed the inclusion of another module on public attitudes to climate change, 10 years after the first was conducted. This proposal was based on obtaining insights into attitudes on one of the country's national priorities, maintaining linkages with European partners by incorporating questions from the 2016 European Social Survey's climate change and energy module, and providing trend information from the 2007 module (Roberts, 2020, personal communication). A set of items relating to these topics was developed, and the module was fielded at the end of 2017 with 3 164 respondents. The questions included items about: knowledge and concern about climate change, views on the causes and impacts of climate change, responsibility for action, and support for interventions. The figure below presents some key findings from the study.

Figure 3: Some results from SASAS on Climate Change (2017)



ENERGY

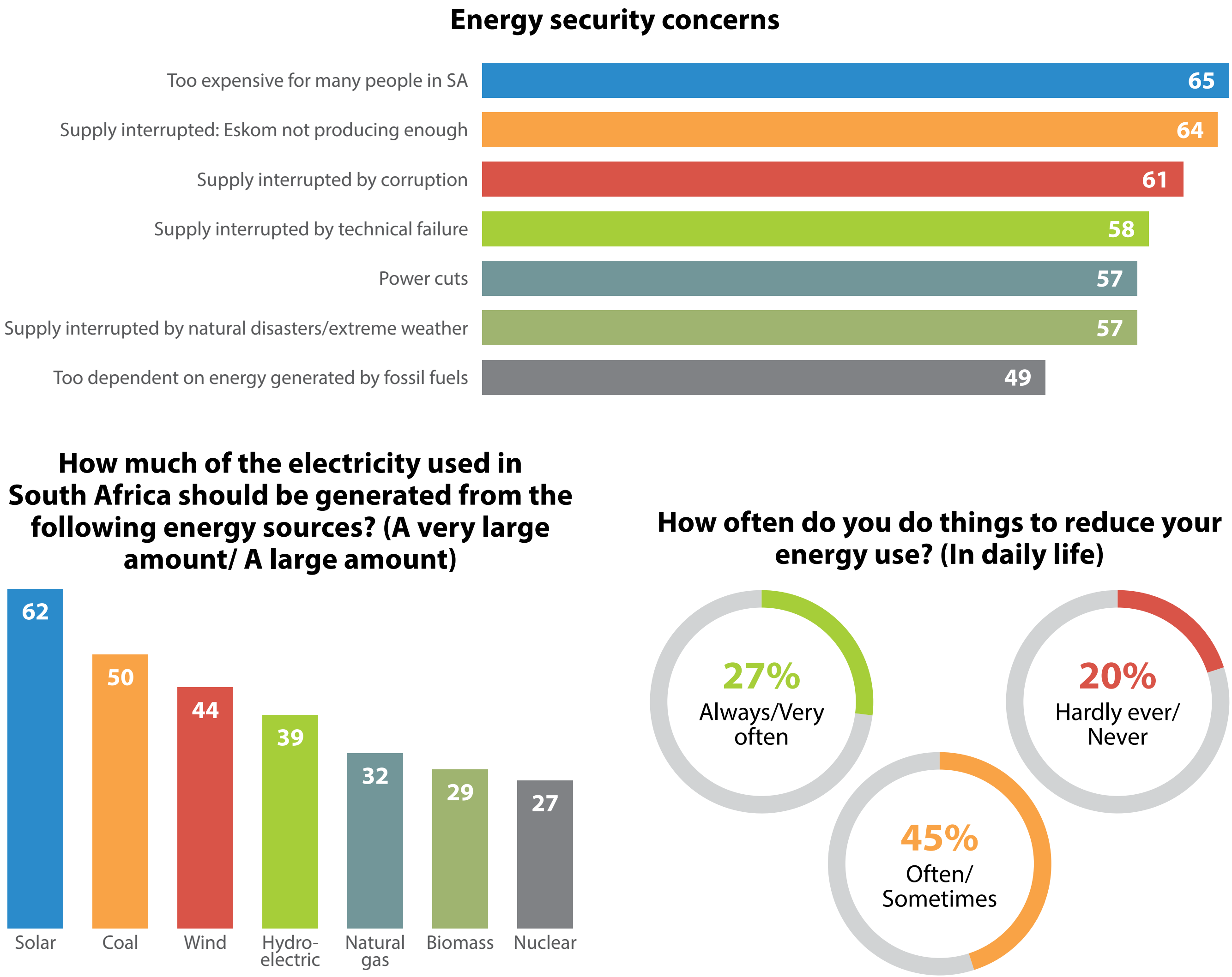
The NDP envisaged that by 2030 South Africa will have an energy sector that promotes: 1) economic growth and development through adequate investment in energy infrastructure; 2) social equity through expanded access to energy; and 3) environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change (National Planning Commission, 2012). In October 2019, a new Integrated Resource Plan (IRP) was gazetted (Government Gazette 652), setting out the direction for the country's energy sector. The IRP provides a development plan for electricity infrastructure, based on the least-cost electricity supply and demand balance, and taking the security of supply and the environment into consideration. The IRP supports a diverse mix of energy and sets out policy decisions to ensure the security of South Africa's electricity supply (RSA, 2019).

Concerns around energy have been growing in South Africa in recent decades, in association with the use of coal (a finite resource) as an energy source, and power interruptions, largely as a result of a lack of maintenance of associated infrastructure and as a result of load shedding by Eskom, the country's primary power supplier (generating approximately 90% of the electricity used in the country) (Eskom, 2019). As a result, it is critical to understand the energy landscape in South Africa, including the public's attitudes in relation to energy.

In 2008, the HSRC was commissioned to do a study on energy attitudes and behaviour amongst poorer South Africans. The HSRC then suggested conducting a nationally representative module through SASAS, which would allow the comparison of the attitudes and behaviours of people from different socioeconomic backgrounds. The argument for such a module was further promoted by the introduction of load shedding in the country (Roberts, 2020). In 2011, 2012 and 2013, modules on energy were included in SASAS. In 2017, questions related to energy were included in a climate change and energy module in SASAS. In 2018, questions on energy were included in a module that was self-funded by the HSRC (Roberts, 2020, personal communication). The modules on energy have sought to find out about household energy sources, energy expenditure, energy needs, electricity-quality and cost, ways to save energy, and electricity provision in South Africa.

The 2017 module was conducted with 3 164 respondents. The following figure provides some findings from the survey.

Figure 4: Some results from SASAS on Energy (2017)



ENVIRONMENT

The Bill of Rights within the South African Constitution (RSA, 1996: 9) stated that 'Everyone has the right (a) to an environment that is not harmful to their health or wellbeing; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that (i) prevent pollution and ecological degradation; (ii) promote conservation; and (iii) secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development'.

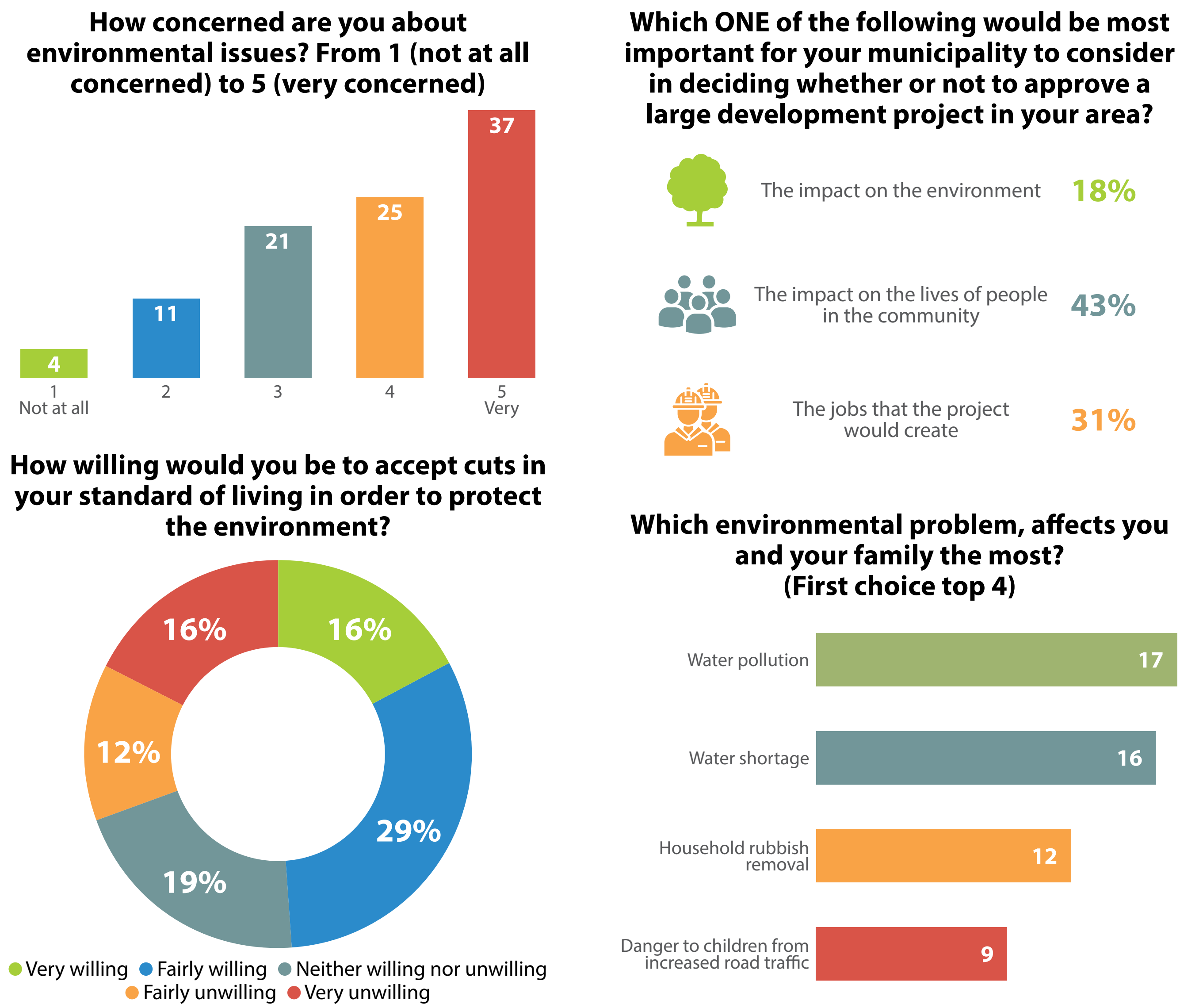
South Africa faces several environmental challenges, and the NDP emphasised the importance of building environmental sustainability and resilience. The NDP highlighted that the country needs to: 1) protect the natural environment in all respects, leaving subsequent generations with at least an endowment of at least equal value; 2) enhance the resilience of people and the economy to climate change; 3) extract mineral wealth to generate the resources to raise living standards, skills and infrastructure in a sustainable manner; and 4) reduce greenhouse gas emissions and improve energy efficiency (National Planning Commission, 2012).

Questions related to the environment have been fielded through SASAS in three years: 2004, 2010 and 2013. In 2004, the module was driven by an HSRC researcher's interest in the topic. The HSRC is part of the International Social Survey Programme (ISSP), and the 2010 environment module was included in SASAS as a commitment to the ISSP. The module which has been included in the 2019 SASAS, which is being fielded in early 2020, is also part of the ISSP. The 2013 module was included as part of a project funded by National Treasury, through the City Support Programme, which incorporates the environment as one of its priority themes (Roberts, 2020, personal communication).

The questions asked in the surveys related to the state of the environment, pollution, genetic modification, governmental involvement, environmental issues, people vs environment, responsibility for protecting the environment, and costs of environmental protection.

The 2013 sample consisted of 2 739 respondents. Figure 5 provides an overview of some of the results of the 2013 module.

Figure 5: Some results from SASAS on the Environment (2013)

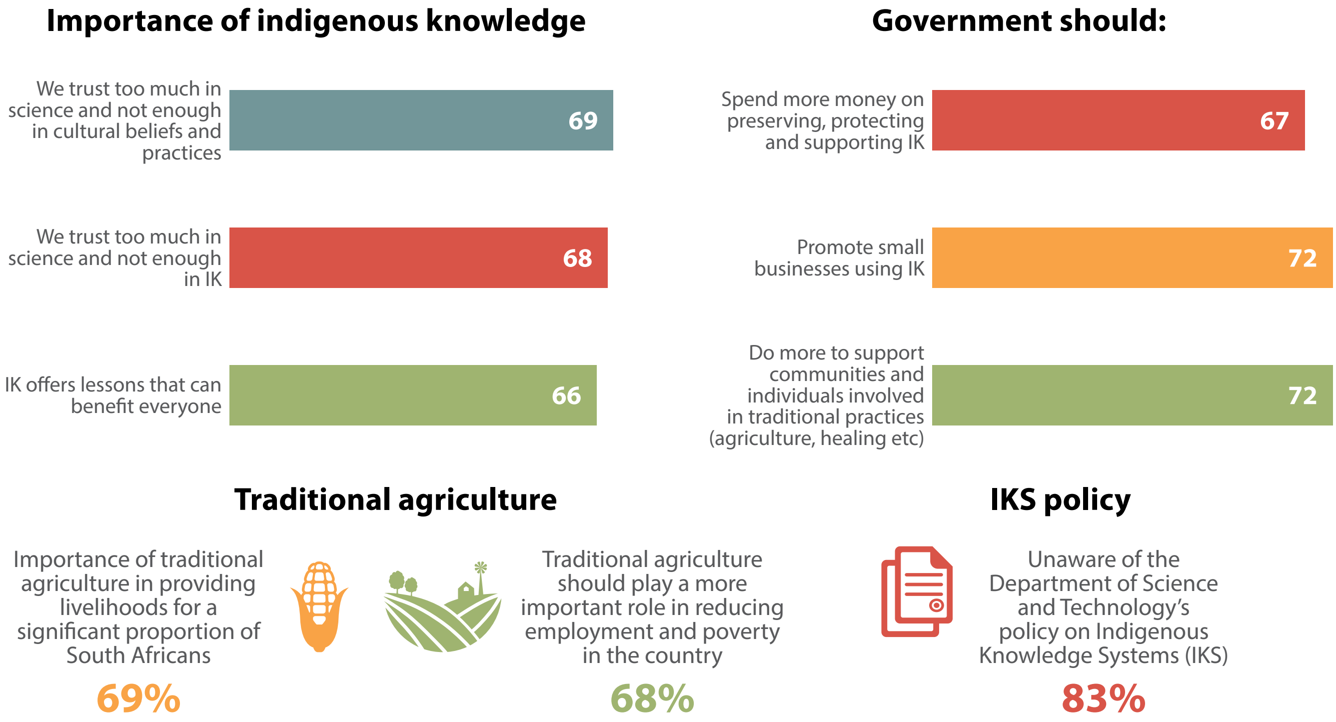


INDIGENOUS KNOWLEDGE

The importance of recognising the value of indigenous knowledge (IK) has been part of the South African agenda for some time. In 2016, the Protection, Promotion, Development and Management of Indigenous Knowledge Systems Bill was introduced. The Bill recognises 'that indigenous knowledge is a national asset and that it is therefore in the national interest to protect and promote Indigenous Knowledge Systems through law, policy and both public and private sector programmes'; aims 'to encourage the use of indigenous knowledge in the development of novel, socially and economically applicable products; and acknowledges 'that indigenous innovation is a unique approach to social innovation that informs and underpins the work of indigenous communities' (RSA, 2016).

In 2009, the HSRC was commissioned by the DSI to include a module on indigenous knowledge in the SASAS as a priority area for them (Roberts, 2020). This is a topic which is particularly relevant in South Africa, given the country's history and rich cultural diversity. The questions asked focused on the respondents' opinions of indigenous knowledge, Government promotion of indigenous knowledge, roles in indigenous knowledge, and sources of information relating to indigenous knowledge. The sample included 3 307 respondents. The figure below presents some of the highlights from the module.

Figure 6: Some results from SASAS on Indigenous Knowledge (2009)

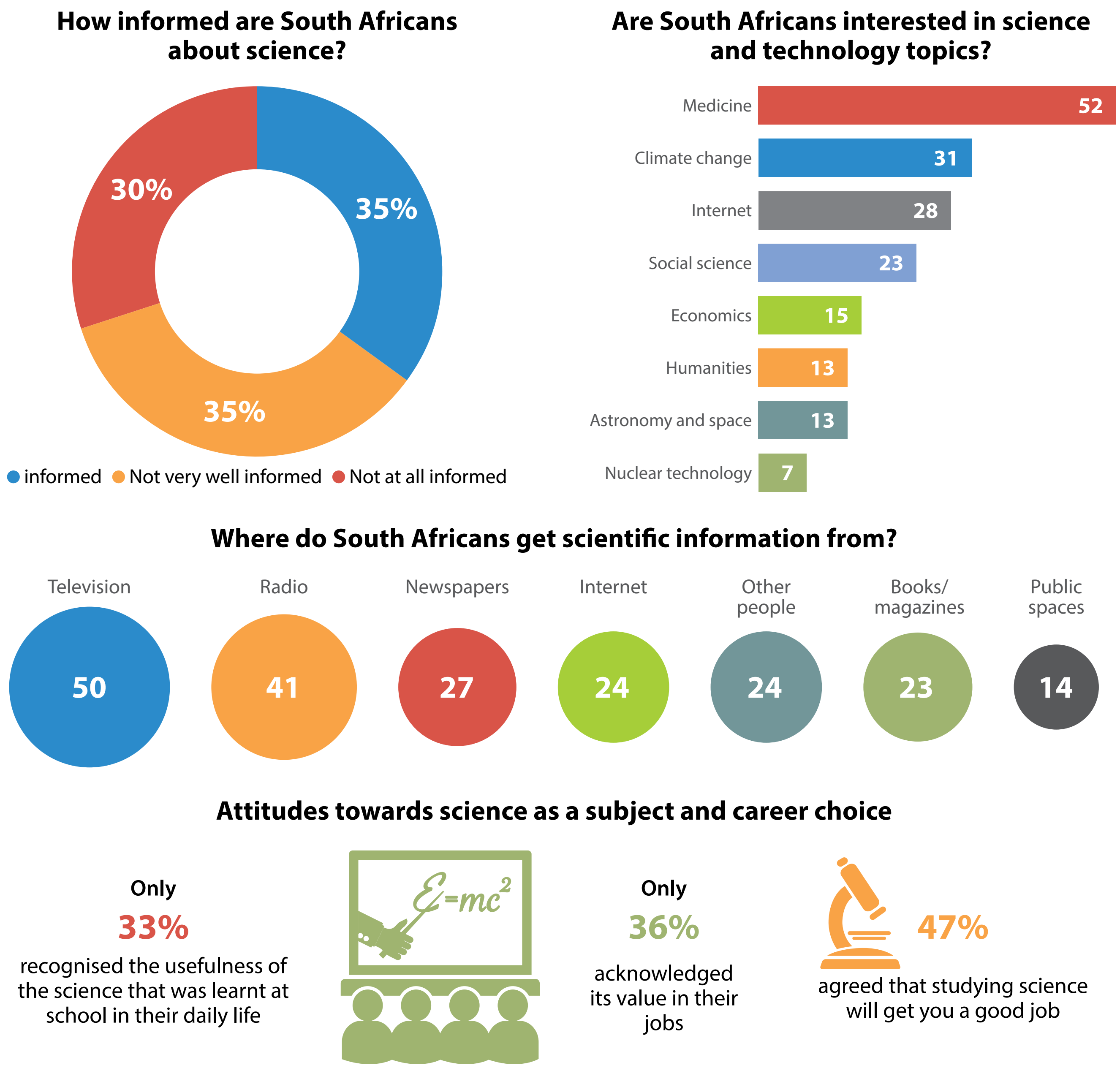


PUBLIC RELATIONSHIP WITH SCIENCE

Besides modules on specific S&T topics, SASAS has also fielded modules focusing on the public relationship with science more broadly. It is important to be aware of the public's knowledge of S&T, their attitudes towards S&T, their interest in S&T, and their related behaviour. In 2010 and 2013, modules on the public relationship with science were fielded, as part of the HSRC's desire to build research in this field. In 2013, a module of 40 items was included. The sample consisted of 2 739 adults over the age of 16. These modules focused on views about science (promise-reservation index) sources of scientific information, science knowledge, interest in science and technology developments, science at school and as a career choice, and visits to science centres and museums.

The results of both surveys showed that generally South Africans expressed positive attitudes toward science. However, the statements that measured attitudes about the benefits of science showed a general decline from 1999 when these questions were introduced to the study. Further analysis indicated that the items which measured scepticism towards science showed that the South African population seems to have become more cautious about the level of trust they place in science, and more concerned about the impacts of science (Reddy et al., 2014). Figure 7 highlights some of the results of the 2013 survey.

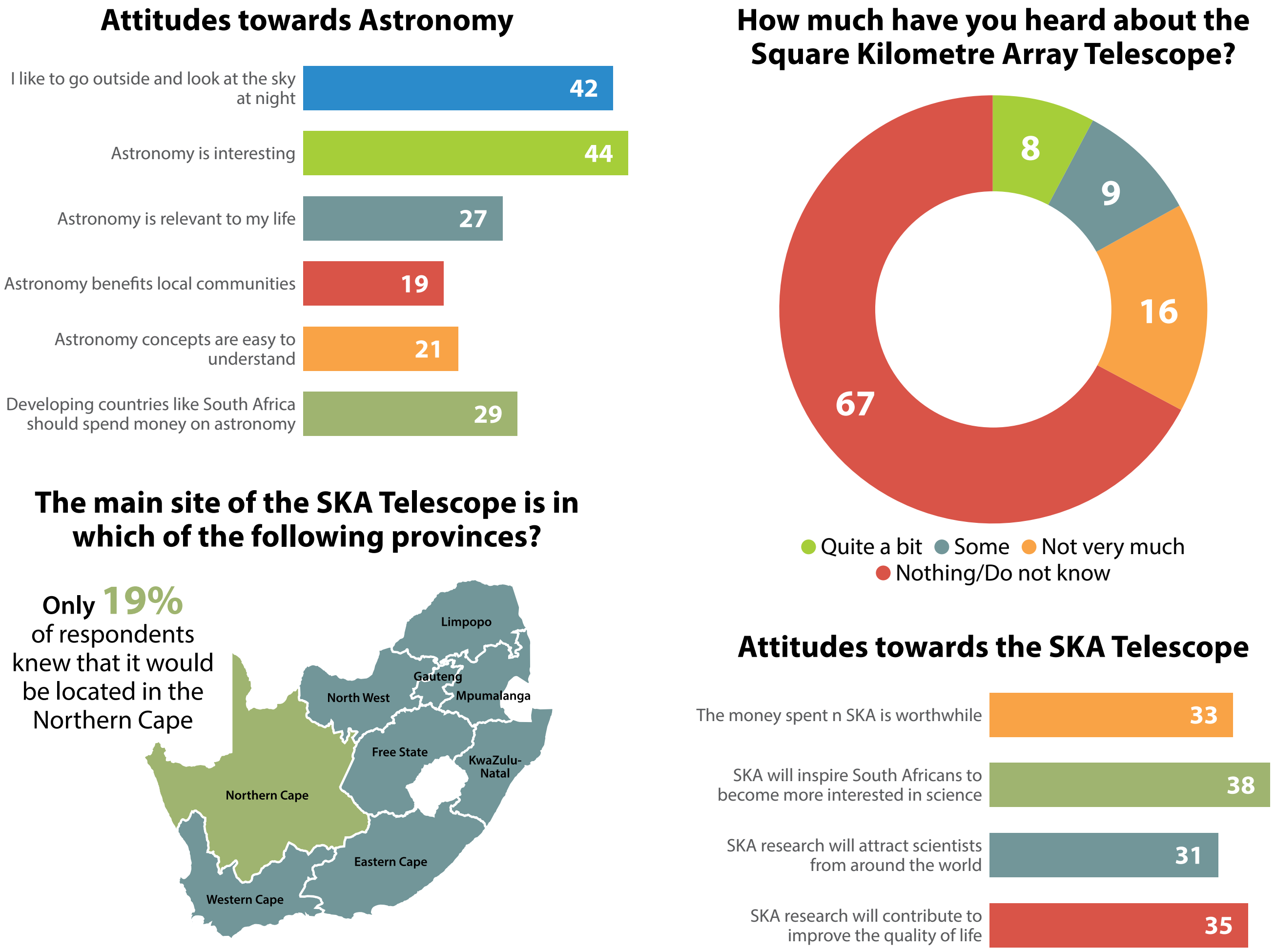
Figure 7: Some results from SASAS on the Public Relationship with Science (2013)



PUBLIC UNDERSTANDING OF ASTRONOMY AND THE SKA

The promotion of public understanding of astronomy has become increasingly important in South Africa, which was successful in its bid to host the Square Kilometre Array (SKA) telescope: a global science and engineering project to build the world's largest radio telescope. The SKA is being undertaken through collaboration between institutions in 20 countries worldwide. It will be hosted in the Karoo Region of the Northern Cape in South Africa, and in Australia. The SKA telescope aims to play an important role in astronomical observation, as well as driving development in information and communication technology. It is set to be fully operational in 2024 (Reddy et al., 2014). The 2013 module on the public relationship with science therefore also included questions about astronomy and the SKA Telescope. The figure below presents the relevant results.

Figure 8: results from SASAS on the Understanding of Astronomy and the SKA (2013)



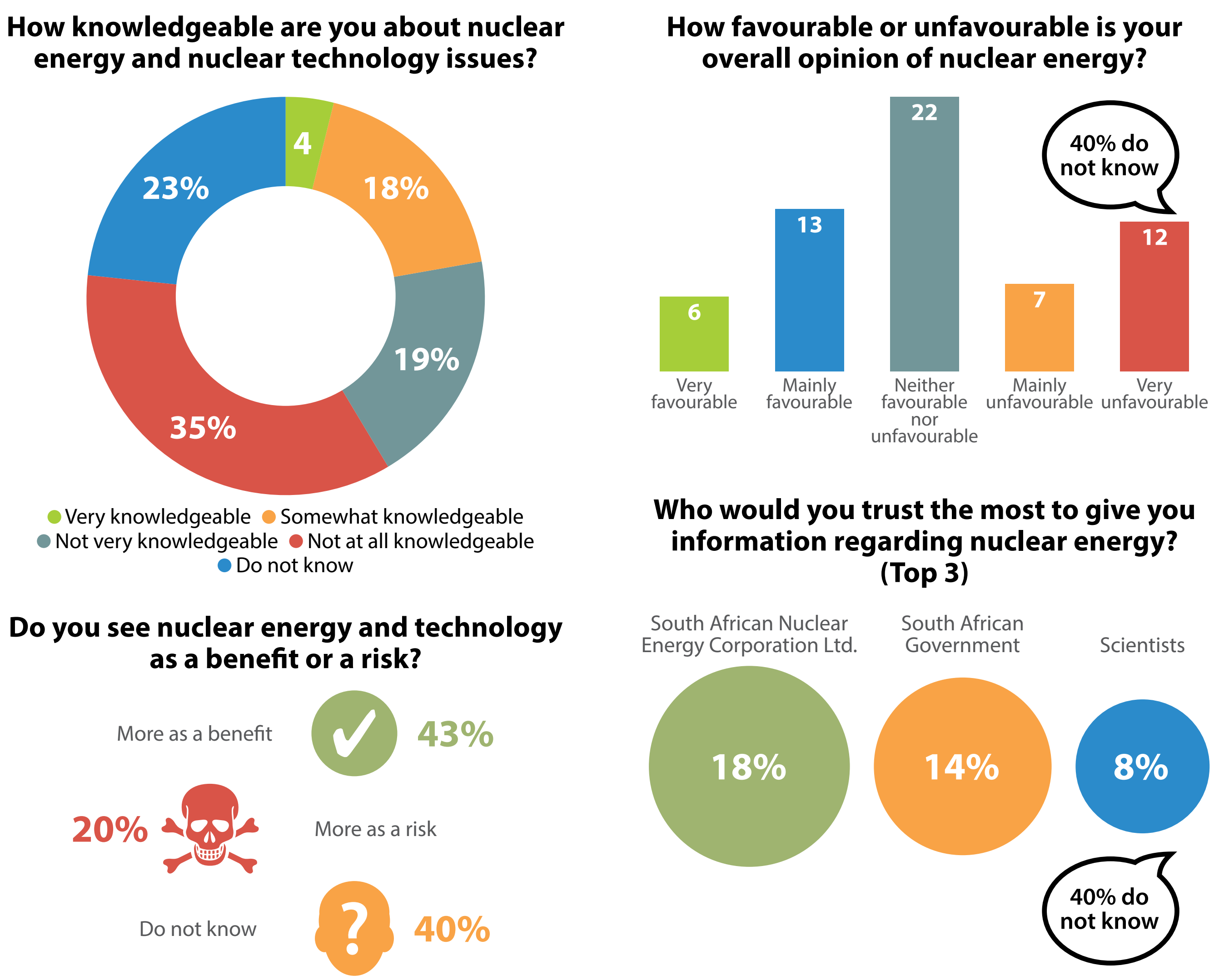
NUCLEAR ENERGY/TECHNOLOGY

The 2019 Integrated Resources Plan (RSA, 2019) highlighted the need for additional nuclear capacity, owing to the decommissioning of capacity from coal post 2030 and the end of the design life of the Koeberg nuclear power plant. Decision 8 in the IRP therefore states: 'Commence preparations for a nuclear build programme to the extent of 2 500 MW at a pace and scale that the country can afford because it is a no-regret option in the long term.'

Due to the controversy which surrounds the use of nuclear energy/technology, both in the scientific and public domains, it is crucial to have an understanding of what the public knows about these areas, and what their attitudes towards their application are. Nuclear energy/technology was included in SASAS in 2011, 2012 and 2013. The HSRC was commissioned by the Nuclear Energy Corporation of South Africa (Necsa), to conduct a study on attitudes to nuclear energy, which was included as a module in SASAS. At the time, there was a change in global attitudes due to widespread concern regarding the use of nuclear energy, partly as a result of the Fukushima Daiichi nuclear disaster in Japan. As a result, many countries were rolling back their nuclear energy programmes. At the same time, South Africa's Integrated Resource Plan was encouraging the use of nuclear energy, with a new power plant planned outside of Jeffrey's Bay. It was therefore a priority to understand South Africans' attitudes to nuclear energy (Roberts, 2020, personal communication).

The modules incorporated questions related to knowledge about nuclear energy/technology, its associated risks and benefits, its uses, the role of nuclear energy in South Africa, and the role of Government; and sources of information about the topics. The 2013 module consisted of a sample of 3 057 South African adults. Figure 9 presents some of the findings from this module.

Figure 9: Some results from SASAS on Nuclear Energy/Technology (2013)

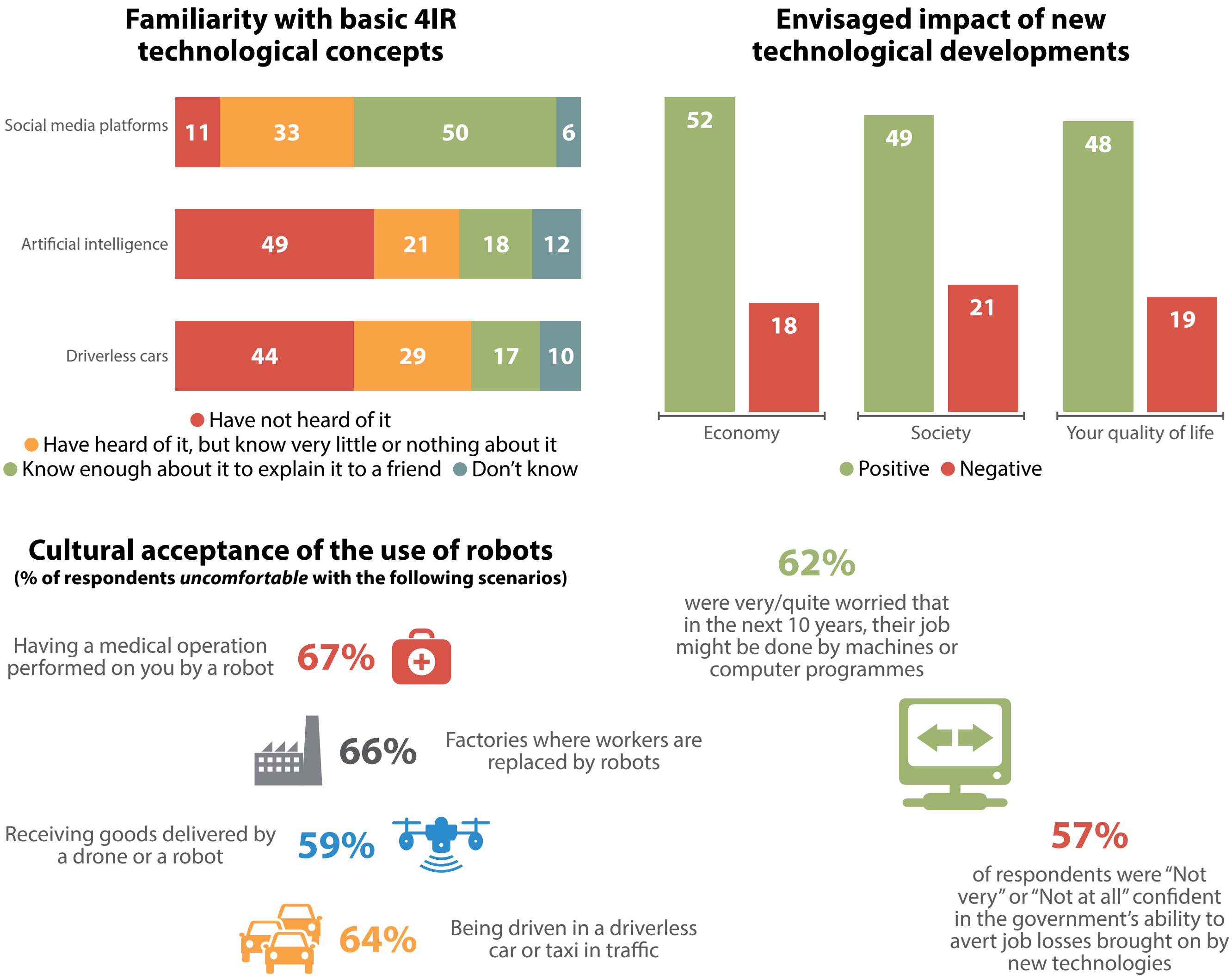


THE FOURTH INDUSTRIAL REVOLUTION (4IR)

The Fourth Industrial Revolution (4IR) has become a global buzzword, and an important focus in scientific and social science research. The idea that we are in a 4IR is premised on the observation of accelerating technological change, the convergence of technologies, and the velocity, scope and impact of these changes. Based on this, there is some consensus that we have entered a new technological era (Gastrow, n.d.).

By 2016, the HSRC had begun to explore the concept of the 4IR, and was focused on developing an institutional response to the 4IR, including a position statement, co-ordination with internal and external stakeholders, and capacity development. The key objective was to develop a research agenda that would provide an empirical understanding of the 4IR in order to inform policy (Gastrow, n.d.). A module of experimental questions on public attitudes towards the 4IR was fielded as part of the 2018/19 round of the SASAS (Roberts et al., 2019). This was used as a means of obtaining some primary evidence as a basis for future work in this area (Roberts, 2020). The survey consisted of 2 736 respondents. Figure 10 presents some of the results from this module.

Figure 10: Some Results from SASAS on the 4IR (2018)



SASAS has been able to generate knowledge which can be used to inform policy development and planning in the country. SASAS has also had important policy reach, through its usefulness as an anticipatory or predictive mechanism, and the provision of information on the country's socio-political climate. SASAS has achieved recognition among policy makers for providing reliable social indicators and attitudinal measures. Examples of the policy reach of SASAS data in relation to S&T in the country include the use of data: 1) to determine individual energy poverty and energy-related behaviour for the Department of Energy; 2) to measure knowledge of and public attitudes towards, science, and to inform the science engagement work of the DSI; 3) to provide an overview of public perceptions on nuclear technology and energy for the Nuclear Energy Corporation of South Africa in an effort to inform public outreach; 4) to provide data to inform evidence-based policies and strategies related to biotechnology, particularly in terms of public engagement and communication strategies, for the South African Agency for Science and Technology Advancement's (SAASTA) Public Understanding of Biotechnology Programme; and 5) to measure public attitudes to climate change and energy through a module funded by the DSI.

5.4 World Values Survey

The World Values Survey (WVS) is a global network of social scientists studying changing values and their impact on social and political life, led by an international team of scholars, with the WVS Association and WVSAWV Secretariat headquartered in Austria. The WVS, which started in 1981, is conducted in approximately

45 countries. There have been six waves of the WVS, carried out in 1981, 1990–1991, 1995–1996, 1999–2001, 2005–2006 and 2010–2014. It consists of nationally representative surveys, and is conducted in almost 100 countries. According to the survey's website, it is the 'largest non-commercial, cross-national, time series investigation of human beliefs and values ever executed' (World Values Survey, n.d.).

The survey aims to investigate socio-cultural and political change across the world, helping scientists and policy makers understand changes in peoples' beliefs, values and motivations (World Values Survey, n.d.). The survey monitors cultural values, attitudes, beliefs and experiences in relation to a range of topics including gender, family, poverty, education, health, social tolerance, cultural differences, and science and technology. The minimum sample size in most of the participating countries is 1200. Samples must be nationally representative of adults aged 18 and over residing within private households in each country, regardless of their nationality, citizenship or language. Probability sampling, or a combination of probability and stratified sampling, can be used. However, the national team should aim to obtain as many Primary Sampling Units (starting points in case of random route sampling) in the sample as possible. The main method of data collection is face-to-face interviews. The answers given by respondents may be recorded using a paper questionnaire or by Computer Assisted Personal Interview (CAPI) (World Values Survey, n.d.).

The most recent World Values Survey conducted in South Africa was in 2013 with 3 531 participants aged 16 and over. A multi-staged sampling methodology was used and the sample was drawn in stages. The questionnaire was translated into Afrikaans, Sesotho, Setswana, isiXhosa and isiZulu. The table below provides the responses related to the attitude scale on science and technology.

Table 15: Responses (%) to Attitude Scale Questions (2010–2014 Wave)

Rating (1 = completely disagree, 10 = completely agree)										
Statement	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Science and technology are making our lives healthier, easier and more comfortable.	1.1	0.3	1.3	4.1	10.7	13	16.4	21.4	9.6	19.1
Because of science and technology, there will be more opportunities for the next generation.	1.1	0.6	1.4	3.9	12.1	14.7	17.6	16.7	10	19.2
We depend too much on science and not enough on faith.	2.8	0.9	2.7	4.7	13.4	15.6	17.4	16.1	9.1	12.5
One of the bad effects of science is that it breaks down people's ideas of right and wrong.	3.4	1.1	2.1	6	13.7	19.2	16.6	15.1	7.1	10
It is not important for me to know about science in my daily life.	5.3	2.3	4.1	6.6	14.1	15.4	17.3	15.1	6.5	10.4
Rating (1 = the world is a lot worse off, and 10 = the world is a lot better off)										
Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Would you say that the world is better off or worse off because of S&T?	2.6	0.7	2.6	3.9	10	14.5	17.3	20	11.9	13.2

Adapted from DataFirst (2017)

Many of the attitudes towards science and technology were positive. Sixty-seven per cent (67%) of respondents rated the statement 'Science and technology are making our lives healthier, easier and more comfortable' between 7 and 10 (extent of agreement). The statement: 'Because of science and technology, there will be more opportunities for the next generation' was rated between 7 and 10 by 64%; and when asked if they thought the world is better off, or worse off, because of S&T, 62.4% answered between 7 and 10, rating it as better off to various extents.

Despite these positive views, around half rated the following statements between 7 and 10 (levels of agreement): 'We depend too much on science and not enough on faith' (55%), 'One of the bad effects of science is that it breaks down people's ideas of right and wrong' (49%), and 'It is not important for me to know about science in my daily life' (49%). The responses to these statements indicate a level of uncertainty or concern about the importance and influence of S&T in society.

The data produced by the World Values Surveys has been used by various stakeholders, including sociologists, political scientists, anthropologists, social psychologists and economists to analyse diverse topics such as democratisation, economic development, gender equality, religion, social capital and well-being. Furthermore, these data have been widely used by government officials, research organisations, journalists and students. Over 1 000 publications in 20 languages have been produced by the WVS network, and secondary users have produced several thousand additional publications (World Values Survey, n.d.). Wave 7 of the World Values Survey began in 2017 and continues until 2020. Data and all related survey documentation will be made available in July 2020 (World Values Survey, n.d.).

5.5 Afrobarometer

Afrobarometer is a non-partisan, Pan-African research institution that conducts public attitude surveys on topics related to democracy, governance, the economy and society in more than 30 African countries. These surveys are repeated on a regular cycle (Afrobarometer, n.d.). In 1999, three independent survey research projects merged to form the Afrobarometer; the three core partners being Michigan State University, the Institute for Democracy in South Africa, and the Center for Democratic Development in Ghana. Since 1999, seven rounds have been conducted (1999–2001, 2002–2004, 2005–2006, 2008–2009, 2011–2013, 2014–2015, and 2016–2018). Starting with 12 countries in the first cycle, Afrobarometer coverage has progressively increased over time, covering a total of 36 countries in Round 6 (2014–2015) (Afrobarometer Network, 2017). The seventh round was conducted in 34 African countries, including South Africa, across which 45 823 respondents were surveyed.

The vision is to create a regularly updated data bank of public opinion surveys in a range of African countries, sustained by a Network of African institutions. The project therefore aims to strengthen institutional capacities in survey research, through the exchange of survey skills among institutions, the transfer of relevant survey technologies from outside Africa, and assisting non-African institutions to adapt survey methods and interpret survey results in the light of African realities (Afrobarometer Network, 2017). National partners are selected to work with in each survey country; they are responsible for training the interviewers, making sure they have the right skills and qualifications, and for the data collection and dissemination (Afrobarometer, n.d.). The Afrobarometer team in South Africa was led by the Institute for Justice and Reconciliation and Plus 94 Research (Nonjinge, 2018). In addition to having National Partners in each country, Afrobarometer is a joint enterprise of the Institute for Justice and Reconciliation in South Africa, the Center for Democratic Development in Ghana, the Institute for Development Studies at the University of Nairobi in Kenya, and the Institute for Empirical Research in Political Economy in Benin. The network also receives additional technical support from Michigan State University and the University of Cape Town (Afrobarometer Network, 2017).

The Afrobarometer conducts face-to-face interviews in the language of the respondent's choice with nationally representative samples, consisting of 1 200 to 2 400 people in each country (Afrobarometer, n.d.). The same questionnaire is applied to every respondent in each country, using identical or functionally equivalent items (Afrobarometer Network, 2017). Previous survey rounds used the paper and pencil interviewing (PAPI) technique, however, in the most recent round, Afrobarometer shifted to computer-assisted personal interviewing (CAPI) using tablets (Afrobarometer Network, 2017).

The Afrobarometer asks respondents various questions related to areas including democracy and governance, violence and safety, news information sources, service provision, police services, prominent issues in the country, religion, and emigration, among others. In the seventh round of the survey (2016–2018), the survey asked questions related to climate change. The study was undertaken in South Africa in 2018, with 1 800 adult respondents in English, Afrikaans, North Sotho, South Sotho, Setswana, Shangaan, Swazi, isiXhosa and isiZulu (Nonjinge, 2018; Selormey, Dome, Osse, and Logan, 2019). The results from South Africa and those of other selected African countries surveyed are shown in the table below.

Table 16: Perceptions of Climate Change Afrobarometer (Round 7: 2016–2018)

	Botswana	Ghana	Lesotho	Mozambique	Namibia	Uganda	Zambia	South Africa	Africa
Have you heard of climate change? (yes)	51%	52%	44%	52%	52%	78%	54%	41%	58%
What does the phrase 'climate change' mean to you? (negative)	30%	26%	33%	27%	26%	58%	30%	24%	38%
Climate conditions for agricultural production gotten worse (past 10 years)	33%	41%	79%	23%	34%	85%	33%	35%	49%
Increased severity of droughts (past 10 years)	37%	30%	79%	32%	38%	87%	27%	37%	49%
Increased severity of flooding (past 10 years)	31%	27%	14%	22%	25%	12%	30%	24%	31%
Climate change caused by human activity	39%	41%	61%	21%	30%	53%	45%	46%	32%
Climate change literate population[21]	22%	21%	24%	12%	16%	46$	22%	17%	28%
Climate change effects worsening quality of life	61%	56%	88%	31%	64%	93%	57%	53%	67%
Ordinary people can do 'a little' or 'a lot' to stop climate change	42%	55%	48%	34%	36%	67%	48%	36%	51%

Adapted from Selormey et al. (2019)

21 'Climate change literate respondents' were considered as those who were not only aware of climate change, but who also understand both the human role in causation and the negative consequences of climate change.

Less than half (41%) of South African respondents reported having heard about climate change. This was lower than the African average of 58%, and South Africa was placed 31 out of the 34 countries surveyed. When asked the question: 'What does the phrase 'climate change' mean to you?', less than a quarter (24%) associated climate change with negative changes in the weather, 'like more droughts, floods or extreme heat'. In relation to this question, South African was again below the average of 38% of Africans that recognise the negative consequences of climate change, in 32nd position out of the 34 countries. Just more than half (53%) felt that the effects of climate change are worsening the quality of life in the country, highlighting a more positive view than the African average of 67%, with South Africa being 27th out of the 32 countries in which this question was asked.

Approximately a third of the respondents (36%) were of the opinion that ordinary people can do 'a lot' or 'a little' to stop climate change. This was 15% below the average, and showed a low level of self-efficacy in relation to what individuals can do, placing South Africa 27th out of 33 countries. Using the survey results, citizens in each country were classified as either 'climate change aware' or 'climate change literate', referring to those who were not only aware of climate change, but who also understood both the human role in causation and the negative consequences of climate change. Only 17% of South Africans were classified as 'climate change literate', placing them 28th out of 33 countries, below the average of 28%. South Africans therefore seem to be less aware about climate change and its impacts than many other countries on the continent.

The Afrobarometer aims to produce information that is helpful to policy makers, analysts, activists, investors, donors, teachers and scholars. It also provides information for ordinary Africans about the attitudes of other people in their countries and across the continent, and provides a platform to voices that might not otherwise be heard, allowing them to become more informed and engaged citizens (Afrobarometer Network, 2017).

Country reports and briefing papers for each round are published on the Afrobarometer website, together with Summaries of Results providing frequencies and disaggregation for all variables at various levels. In Round 6, new formats for disseminating the results were introduced, including Dispatches and Policy Papers, both of which provide a quick and easily accessible overview of important findings on selected topics of interest to policy makers or advocates. By May 2017, the Network had published 147 Dispatches, 40 Policy Papers, 159 Briefing Papers and 172 Working Papers, which are full-length analytical pieces written for publication in academic journals or books. Two Afrobarometer books have also been published: *Public opinion, democracy, and market reform in Africa* was released in October 2004, and *Voting and democratic citizenship in Africa* was published in 2013. After Round 5, a series of Global Release events were introduced in cities across the continent. These events have received extensive media coverage and helped to build Afrobarometer's profile, both in Africa and globally. The Afrobarometer website is a principal vehicle for the dissemination of information. The website also links to the Network's Online Data Analysis facility, which allows users without access to the software or technical skills required for data analysis to access data and generate basic frequencies, crosstabs and graphics online (Afrobarometer Network, 2017).

In order to increase the strength of the Afrobarometer Network, a number of activities are undertaken. These include periodic planning and capacity-building workshops; the provision of Afrobarometer Fellowships for individual study and training; Technical Assistance Exchanges and Mentoring Exchanges for one-on-one training, mentoring and support; and the co-ordination of Afrobarometer Summer Schools, which provide in-depth training in data analysis and reporting (Afrobarometer Network, 2017). The aim of these activities is to enhance and promote both the technical and managerial skills required to sustain an ongoing programme of survey, research, analysis and outreach (Afrobarometer Network, 2017).

Round 8 of the Afrobarometer is planned in at least 35 countries for 2019/2020.

5.6 Development of a Test for Basic Scientific Literacy

In 1996, Rudi Laugksch's was awarded his PhD, which focused on scientific literacy among matriculants entering certain tertiary institutions in the Western Cape. The dissertation was entitled *Development of a test for scientific literacy and its application in assessing the scientific literacy of matriculants entering universities and technikons in the Western Cape* (Laugksch, 1996). The purposes of the study were (a) to determine the level of scientific literacy of matriculants entering tertiary education in the Western Cape, (b) to describe patterns of scientific literacy for selected demographic and student background variables, and (c) to ascertain which student background variables appear to have the most influence on determining whether matriculants are scientifically literate or not.

The sample consisted of 4 227 first-year students at the Cape Technikon, Peninsula Technikon, University of Cape Town, University of Stellenbosch and University of the Western Cape. Laugksch developed a survey instrument for this purpose. Laugksch based the items for his scientific literacy test on the 1989 American Association for the Advancement of Science (AAAS) report. The questionnaire was constructed around scientific literacy – including questions on the nature of science, science content knowledge, and the impact of science and technology on society. (For more information on this study, see Reddy et al., 2009.)

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

A 2017 PhD thesis by Parker (2017) focused on developing indicators for measuring the public's relationship with science in South Africa. Parker highlighted the importance of science in the country, in relation to the acceleration of development (service delivery and improved quality of life), increasing economic performance (new methods of production and efficiency), and improving democracy (more engaged public). The public understanding of science therefore becomes a critical factor in accelerating those development ideals (Parker, 2017).

The study set out to develop a set of measurement indicators, and adopted six elements to constitute the South African publics' understanding of science: Knowledge of science, attitudes to science, interest and informedness about science, science information source, and attendance at science engagement activities. The main objectives of the study were to 1) determine the level of South African PUS; 2) understand the patterns of PUS in relation to demographic variables; 3) develop indicators for each of the PUS elements; and 4) determine the key predictors of performance on each of the new indicators. A nationally representative survey was conducted, with 3 486 respondents.

Figure 11: Some Findings on the Public Understanding of Science (Parker, 2017)

Knowledge

41%

provided scientifically correct Moderately positive attitudes responses.

Considerable variation was revealed by topic area: for example: medical science items were answered correctly by 67%, while astronomy items received 28% correct responses.

Attitudes

Moderately positive attitudes to science, with an average of 70% of respondents agreeing with positively worded attitudinal items, while 58% agreed with the more critical attitudinal statements.

Interest

23%

indicated a high level of interest in science, while 33% indicated a moderate level of interest. However, 44% indicated no interest in any of the areas of science listed.

Informedness

46%

reported mid to high levels of informedness.

Information sources

Most popular sources:

Radio (86%}
Newspapers (83%)
Terrestrial Television (83%),
Other people (79%)

Engagement activities

11,5%

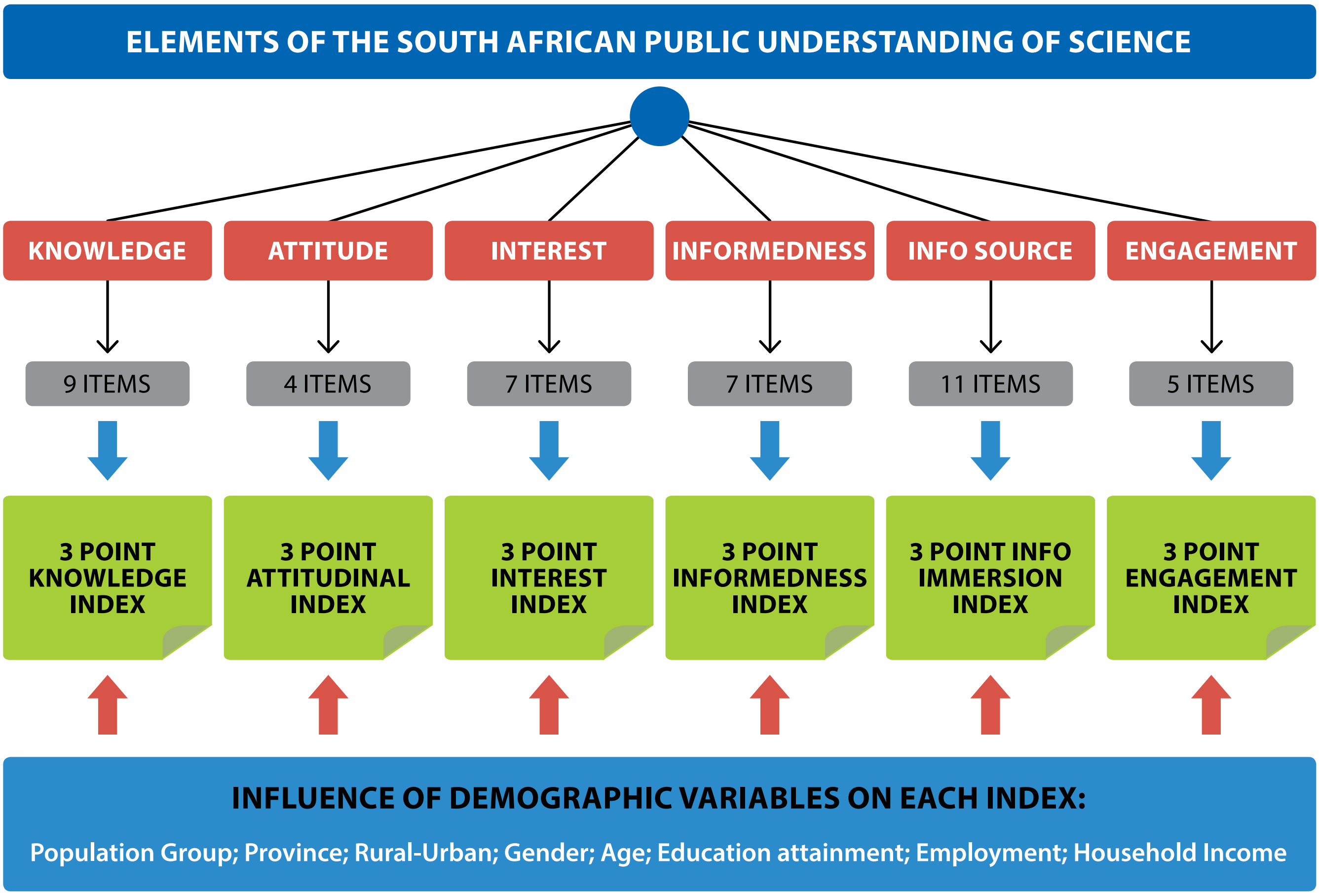
attended (at least) 1 activity, 88.5% did not attend any engagement activity.

Following extensive literature reviews and question comparisons, items were adopted, adapted or developed towards producing the questionnaire. In each question-set, it was ensured that all items carried a high degree of face validity within their respective domains. An assessment of dimensionality was undertaken to ensure that the items within each question-set shared a common latent variable. In addition, assessments of item difficulty, item discrimination, reliability, face, content and criterion validity, as well as construct validity, were conducted. All of these were found to be at an acceptable level (Parker, 2017).

Development of the six indicators relied extensively on a broad reading of the academic literature within this research domain. The South African public understanding of science was assumed to include the six elements presented above. Each of these elements was studied within the research area to adopt, adapt or develop questionnaire items that would best create stand-alone indices. All items were subject to rigorous piloting and evaluation steps to ensure appropriateness to local conditions.[22]

22 These include language and translation consistency, difficulty and reliability assessments.

Figure 12: The South African Public Understanding of Science



Source: Parker (2017)

The *Science Knowledge* assessment includes nine statements requiring a *True*, *False* or *Don't Know* response (e.g. Lightning never strikes the same place twice). *Attitudes to science* were measured using the Index of Scientific Promise and Reservation (Shukla and Bauer, 2009). *Interest* in science was operationalised adopting seven self-reported levels of *interest* in topical areas of science. The dimension related to *informedness* in science was assessed in similar ways to the *interest* items. Both Indices used response options, including *Interested* to *Not Interested* and included a *Don't Know* response option. *Science information sources* assumed 11 key information channels and asked respondents to indicate the frequency of encountering science information within each of the sources listed. *Science engagement activities* among South Africans within the preceding 12 month period was investigated using a question that asks about attendance at various types and modalities of science engagement locations.[23]

These six elements of the South African public understanding of science were analysed with the corresponding demographic data to develop indicators. Beyond the development of indicators, respondent performance and predictors of outcomes on each indicator based on demographic variables were also computed.

Six predictors based on individual's characteristics were explored in relation to the indices created. These were: race group, educational attainment, household income, geographic location (rural/urban), age, and employment status. The following were identified as predictors of the outcomes for each of the indices:

23 These include libraries, zoos, museums, science centres, public talks and festivals.

- Science Knowledge Index: Race, educational attainment, household income;
- Attitudes to Science Index: Race;
- Interest in Science Index: Race, educational attainment, household income;
- Informedness in Science Index: Race, educational attainment, household income, geographic location (rural/urban), age, employment status;
- Information Immersion Science Index: Race, educational attainment, geographic location (rural/urban), age; and
- Science Engagement Index: Educational attainment, geographic location (rural/urban).

Race and educational attainment were the most significant predictors on five of the six indices (Parker, 2017). The significant legacy impact of apartheid on South African society is still acutely visible within research data findings. The most significant predictor of outcomes on the six indicators developed was found in all of them to include the variable of race. Race at its most basic interpretation as a research item is a complex variable. In South Africa race is statistically intertwined with related variables, including educational attainment, employment, income and gender. Despite being 25 years into democracy, these outcomes highlight the significant social and psychological impact that apartheid continues to have on contemporary South African society. As a result of the analysis performed, a more fine-grained picture emerges of the South African publics than has been visible before. Clearer details related to race, gender, income, education and rural/urban location and the many interactions that may help in explaining the unique fingerprint of the South African science culture. The data clearly indicates a significant interest in science among South Africans, however, as a result of interacting socio-cultural and economic realities. Harnessing and directing that interest toward a more positive relationship between science and the public becomes the new challenge. The potential within this data then rests in developing tailored media communications targeting specific audiences and locations – within the preferred or most accessible media format – so that public science communication maximises both its reach and social relevance. The value and impact then rests both in the data snapshot of the South African public relationship with science in 2016 but also in opening up the possibility for future trend analysis within this rich dataset.

5.8 Trends in International Mathematics and Science Study (TIMSS)

The Trends in International Mathematics and Science Study (TIMSS) is an international study which assesses the mathematics and science achievement of Grade 4 and 8 learners[24] in countries around the world, focusing on both content knowledge and cognitive skills. The main aim of the study is to determine the nature and extent of learner achievement in each country, and to understand the context in which it occurs. TIMSS is one of the most established studies of educational quality worldwide, providing comparative data from a diverse set of educational systems (Zuze et al., 2017).

TIMSS was first conducted in South Africa in 1995. Thereafter it was conducted in 1999, 2003, 2011 and 2015. TIMSS 2015 was the first time Grade 5 learners were included in the study in South Africa and were assessed in numeracy. Grade 9 learners were assessed in mathematics and science. The TIMSS 2015 sample was drawn from the 2013 Department of Basic Education (DBE) master list of all schools in the country. A total of 300 schools were sampled, of which 292 participated in the study. A total of 12 514 learners, 334 mathematics and 331 science teachers participated in the study (Zuze et al., 2017).

24 South Africa assesses learners at the Grade 5 and 9 levels.

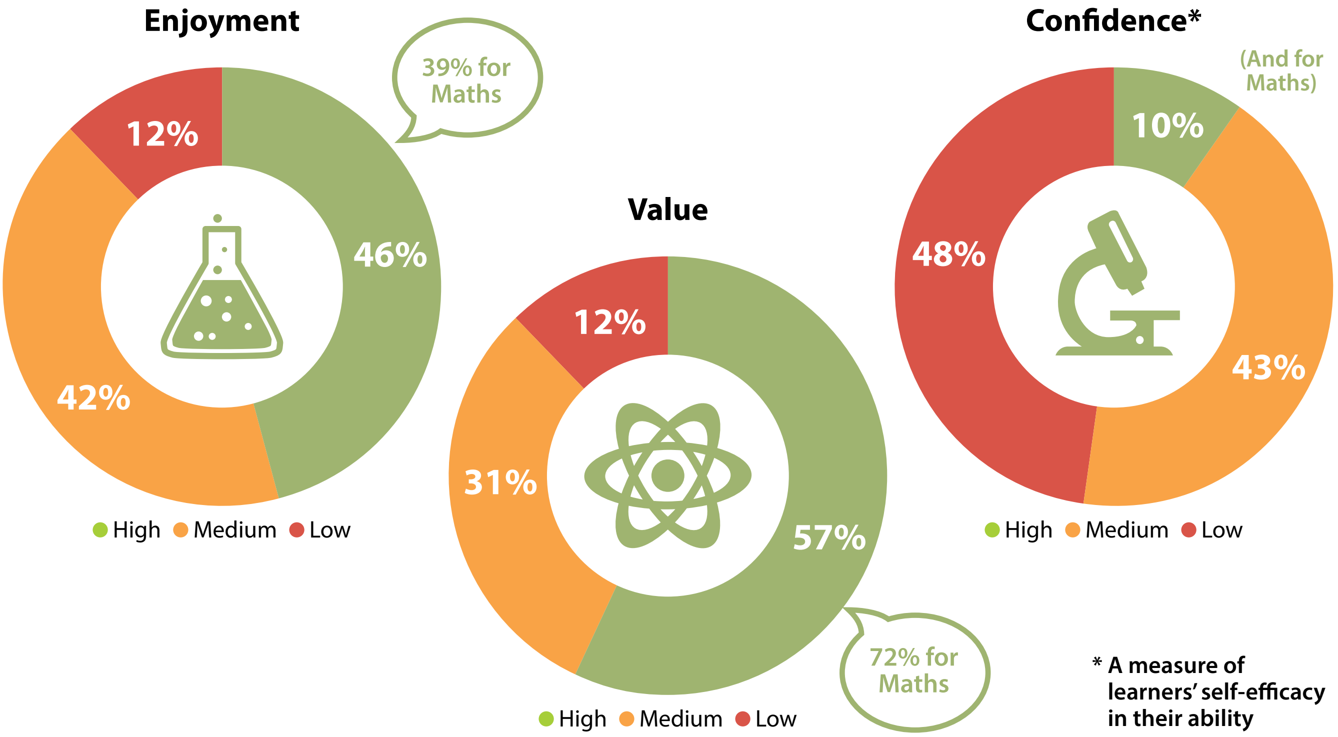
Data collection for the most recent round, TIMSS 2019, has been completed, with data collection for Grade 5 learners occurring in 2018, and data collection for Grade 9 learners having been undertaken in August 2019. For the first time in the country, science was assessed at the Grade 5 level. The Grade 9 study included an extended sample of schools, with approximately 120 additional schools in the Gauteng Province (GP) and the Western Cape (WC) being assessed, in addition to the national sample of approximately 30 schools per province. The results from the most recent TIMSS will be available in December 2020. Learners have historically been assessed using paper and pencil tests in TIMSS. In 2019 half of the countries participated in eTIMSS, and in TIMSS 2023 all countries will have to use eTIMSS.

Table 17: TIMSS assessments conducted in South Africa (1995–2019)

Year	Grade	Number of schools	Number of learners
1995	7	137	5 267
	8	114	4 413
	12	90	3 757
1999	8	194	8 147
2003	8	225	8 952
	9	238	4 261
2011	9	285	10 085
2015	5 (Numeracy only)	297	10 932
	9	292	12 514
2019	5 (Maths and Science)	291	11 955
	9	524 (150 in GP, 149 in WC)	20 880

The instruments which are used in TIMSS include a set of achievement items in mathematics and science which learners are required to complete. These questions focus specifically on learners' content knowledge, and mathematics and science abilities. In addition, a contextual questionnaire is completed by learners, which asks them about their experiences and perceptions. Questions included in this questionnaire focus on the attitudes of the learners to mathematics in science, in terms of their interest in the two subjects, the value they place on these subjects and their confidence in their ability in both subjects. The figure below shows the level of enjoyment, value and self-efficacy of learners in relation to science.

Figure 13: Enjoyment, Value and Confidence in Science in TIMSS (2015)



Consistent with other literature, results have shown that learners who have more positive attitudes to science achieve better results in the subject, although the direction of the relationship is unclear. Juan et al. (2018) used TIMSS 2015 data, and noted a positive relationship between Grade 9 learners' self-efficacy (belief in their ability) in science and their science achievement.

Experiences of science at school shape peoples' attitudes towards the science they are taught at school, as well as the science they encounter outside of school. Attitudes towards science that are formed early in life may have an impact on the relationships that individuals have as adults with science in general (Juan et al., 2018; Reddy et al., 2013). It is therefore important to understand the attitudes of learners to science at a specific point in time and over time to allow for measurement of changes. TIMSS provides critical nationally representative trend data in this regard.

TIMSS provides useful measurement data, trend data and cross-country comparative data. Several publications have been written using attitudinal data from TIMSS, and, through engagements with principals and teachers, we have been able to share the results.

The HSRC has also developed a TIMSS SA website which provides information and resources related predominantly to TIMSS in the country, but also those that focus on mathematics, science and education in South Africa more broadly.

5.9 Concluding comments

A number of empirical studies have been undertaken in South Africa over the last 25–30 years which have focused on the public relationship with science. The frequency of such surveys has increased in the last 15 or so years, particularly through the SASAS, which has included various modules on a range of scientific topics. These surveys have provided valuable information regarding what the public knows and feels about science, in general and in relation to specific topics, such as energy, climate change and biotechnology. The key now is to use this information in the formulation of strategies to promote the public understanding of science.

There have also been a limited number of surveys focusing on learners' knowledge of science, as well as their attitudes towards science. Most notably, TIMSS has provided key insights into the content knowledge and abilities of learners in both mathematics and science since 1995. Furthermore, TIMSS has highlighted the attitudes of learners to science, particularly as a school subject and as a career choice. The TIMSS data has been used as a point of reference to make recommendations as to how mathematics and science achievement can be improved in the country, and to emphasise the importance of attitudes in these subjects.

The first surveys conducted in South Africa were driven primarily by individual researchers in conjunction with an organisation, such as FEST and the HSRC. The later surveys, particularly those on specialist topics, have been driven in part by Government interests, with a few individual interests continuing to initiate surveys. Links to international surveys have also played a role in the modules which have been fielded, such as the SASAS links with the ISSP and the ESS Specialist topics. The HSRC, through SASAS, has also shifted the fielding of public relationship with science modules from an ad hoc approach to a more structured approach of regularly monitoring various measures of the PRS.

6. FINDINGS AND RECOMMENDATIONS

The 2019 White Paper on Science, Technology and Innovation includes the policy intent for a science literate and science aware society. A system wide science engagement co-ordination model will be instituted, going beyond the DSI and its entities, enabling the higher education sector, industry, research councils, science centres and other relevant stakeholders to collaborate on science engagement. Indicators to measure the success of system-wide science engagement performance will be adopted to inform an institutionalised survey on public perceptions of science and country comparison studies.

The HSRC has developed a set of monitoring and evaluation indicators for the science engagement strategy. In addition the DSI has commissioned the HSRC to conduct a periodic survey of the public relationship with science in South Africa. Mapping the public relationship with science provides the basis for us to move forward and plan for the survey within the South African context.

6.1 Key findings

1. Since the publication of the DSI's Ten Year Innovation Plan (2008–2018), there have been significant policy, infrastructure and social developments to support science engagements among the population. These have been supported by the DSI. Strategic policy tools developed to support the science engagement ambitions include the 2015 Science Engagement Strategy and the 2019 White Paper on Science, Technology and Innovation which promises to institutionalise a public and science survey.
2. The public awareness of science has been part of the agenda of the democratic state. The 1996 White Paper on Science and Technology outlined the rationale for a public-awareness-of-science agenda, and the 2019 White Paper advances this idea through an expanded programme to develop knowledge and human capabilities, as well as active science engagement networks in South Africa.
3. The purpose of the enhanced policy, infrastructure and social environment surrounding the public relationship with science is to ensure the development of a South African public that is supportive, yet critical of science. This requires a public that is responsive and engaged with crucial and contemporary debates, as well as with technology's influence on education and the future of work.
4. The recommendation from the 2009 Public and Science Report regarding the need to conduct a national survey on the public understanding of science has been incorporated into the strategic planning of the DSI, and institutionalised through the 2019 White Paper on Science, Technology and Innovation.
5. Theoretical evolutions within the literature have highlighted the three approaches towards understanding the public relationship with science. The preferred and most democratised approach is considered to be the science in society paradigm. This favours a bi-directional learning approach between the public and science, and highlights the importance of communication and engagement. Empirically these approaches need not supersede each other, but may provide greater value in the recognition of their complementary contributions to understanding different aspects of the public relationship with science. This is of particular relevance in South Africa, where scientific literacy is still low.
6. Internationally, there has been a growing number of countries (both high and low-income) conducting public attitudes to science surveys. Some countries undertake these surveys as part of a wider reporting framework, while others formulate specific modules as a response to contemporary issues. These studies have been initiated by both state and private actors, and have been conducted for both the general and school-based populations, in order to improve school science education. Furthermore, the areas which are assessed have expanded over time to incorporate novel but important focuses, such as 'science and politics'.

7. There has been an increase in the number of specialised S&T topics that have been included in these surveys. In South Africa, a number of specialised S&T modules have been incorporated in the South African Social Attitudes Survey (SASAS) series. Many of these modules have been commissioned by Government departments, which highlights the integral role that attitudinal variables are beginning to play in informing science policy making.
8. South Africa has measured public attitudes to science through a few ad hoc surveys or a few items related to public and science included in other surveys. Though incomplete, they have provided a better understanding of the public's relationship with science. These findings provide a wealth of information which can be used by policy makers and relevant stakeholders to identify strategies for the promotion of S&T, and for encouraging greater levels of engagement among all role players, including the public.
9. South Africa's diversity is well recognised, especially concerning education, income gaps, living conditions, language and culture. The findings from the previous report suggested the concept of multiple *publics*, rather than a homogenous *public*. The recognition of the non-homogenous nature of the general public has been adopted in empirical work both internationally and domestically.
10. In South Africa, the methodological approach to conducting these surveys has shifted over time, with increased consideration being paid to the psychometric validity of survey items. In more recent surveys, the need to pose questions in a way that is easily understandable to all, even if respondents do not have specific knowledge of the topic or the linguistic terms used to describe them. This shift allows for more meaningful data to be gathered because it yields fewer vague responses within the dataset. Cross-cultural and linguistic considerations have therefore become important considerations in the development of survey items.
11. The methodologies used to collect data on the public's relationship with science have evolved from the use of face-to-face or telephonic surveys to incorporate new and innovative approaches, such as social listening. The approach to understanding the public relationship with science has expanded to include multiple information sources for one study.

6.2 Recommendations

Building on the recommendations and work completed since the 2009 Science and the Publics Report, together with the above findings, the following recommendations are proposed:

1. A five-yearly survey of the South African Public Relationship with Science will form the primary instrument for data collection to inform this area of research. Complementary methodologies for collecting data and interrogating the public relationship with science must also be explored. These may include qualitative and quantitative methodologies that access specialist groups, community meetings and public hearings as well as evolving 'social listening' technologies within online communities.
2. The intended research instrument within the planned public relationship with science survey should strive to shift methodologically beyond the known measurement tools and adopt a more inclusive and community-focused development approach. This will ensure more representative and valuable data to inform policy and related applications. This must include rigorous piloting and psychometric validations within each item developed.
3. In order to develop inferentially useful indices and research outputs that promote effective evidence-based policy formulation and interventions, appropriate design, analytics and communication strategies must be incorporated throughout the research design phase to ensure that all items are appropriate to domestic realities, while similarly offering a degree of international comparability. Research instruments should account for the diversity present in the South African context in item construction, data collection and the analysis of research findings.

4. More comprehensive understanding of the numerous psychological antecedents of attitude formation within the South African population must be developed. This calls on researchers and scholars to gain a deeper understanding of the psychology of science communication and the most effective modes and means of communication to the various segments of the population.
5. The development of an integrated communications strategy and feedback mechanisms to ensure that bi-directional learning and collaborative data sharing remain part of the PRS survey methodology and implementation. This ensures a greater degree of public engagement as well as knowledge mobilisation within this evaluative process.
6. The South African Government should continue to champion science engagement activities through a long-term plan – leveraging the support of business, civil society and other public actors to ensure a deeper social and intellectual impact of the Science Engagement work programme.
7. Knowledge producers should adapt the culture of work to include both knowledge generation and dissemination activities as integral to their role within the NSI.
8. A fine-grained understanding of the evolving South African political economy must form the background to developing a deeper understanding of South African society and its relationship to science.

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APPENDIX A: INTERNATIONAL SURVEYS ON THE PUBLIC AND S&T[25]

Context	Title	Years	No of respondents	Data collection	Topics
Asia	Climate Asia Surveys (Bangladesh, India, Nepal, Pakistan, China, Indonesia, Vietnam)	2012	31 961 (Bangladesh: 3 578, India: 8 368, Nepal: 2 354, Pakistan: 4 128, China: 5 062, Indonesia: 4 985, Vietnam: 3 486) (aged 15+)	Quantitative survey (Focus group discussions with the public were also used; other stakeholders were also consulted through a range of methodologies)	Awareness of current changes in the environment, levels of knowledge about action to take, current action taken to respond to change, likelihood to take action to respond to changes in future, current use of communication to enable response to changes in the environment
Australia	Australian Attitudes to Climate Change (Longitudinal Survey)	2010–2014	17 493 (4 999 completed 2 or more surveys, and 269 completed all 5) (aged 18+)	Online surveys	Attitudes to climate change, climate-relevant behaviour, climate estimates and projections, adaptation, trust and emotions
	Australian Beliefs and Attitudes towards Science Survey	2017 2018	1 200 1 000	Telephone interviews	Interest, level of informedness, sources of information, attitudes towards science (including a focus on specific topics such as vaccinations, genetic modification, GM foods, animals in scientific research, climate change), occupational prestige
Brazil	Public Perceptions of Science and Technology	2006	2 004	Face-to-face interviews	Interest, informal science institution visits
	Percepção pública da C&T – 2015 Ciência e tecnologia no olhar dos brasileiros (Public Perceptions of S&T – 2015 Science and Technology in the Eyes of Brazilians)	2015	1 962 (aged 16+)	Telephone interviews	Interest in S&T, S&T information sources, visiting scientific-cultural spaces, attitudes to S&T, S&T in Brazil
	Mudanças climáticas: O que pensa o brasileiro (Climate Changes: What the Brazilians Think)	2015	2 100 (over 16 years old)		Knowledge, awareness, causes and impacts, climate-related action
	What do Young Brazilians think of Science and Technology?	2019	2 206 (15–24 years old)	Face-to-face interviews Discussions groups and interviews with people aged 18 to 24 in 2 cities	Access to scientific knowledge, interest in S&T, attitudes to S&T, disinformation and perception of fake news

25 This list of surveys is not exhaustive but gives an overview of the international public, and science and technology, research landscape.

Context	Title	Years	No of respondents	Data collection	Topics
Canada	Public Survey of Science Culture in Canada (Part of a report: Science Culture: Where Canada Stands/ The Expert Panel on the State of Canada's Science Culture)	2013	2 004	Landline and cell phone (60%) Internet (40%)	Public attitudes to S&T, public science engagement, public science knowledge, S&T skills
Canada & USA	Canada–US Survey on Biotechnology	2005	3 200	Random digit dialling (RDD) computer assisted telephone survey	Biotechnology, nanotechnology, and other technology attitudes (includes U.S. data on specific issues)
China	Chinese National Survey of Public Scientific Literacy	1992 1994 1996 2001 2003 2005 2007 2010 2015 2018	5 500 5 000 6 000 8 350 8 520 8 570 10 080 69 360 70 400 60 177	Face-to-face interviews	Civic scientific literacy, attitudes towards S&T, interest in S&T, prestige of S&T occupations, visits to informal science institutions
	China Science and Technology Indicators	2004	8 350	Information not available	Various knowledge and attitude items
Europe	Eurxobarometer/ Special Eurobarometer: Europeans and Biotechnology 35.1/39.1/46.1/52.1/58.0/244b	1991 1993 1996 1999 2002 2005 2010	12 800 13 032 16 246 16 082 16 500 25 000 26 671 (aged 15+)	Face-to-face interviews	Knowledge, awareness, attitudes towards use of biotechnology, technological optimism and pessimism; evaluating applications of biotechnology, stem cell research, governance, trust and information, engagement and involvement
	Special Eurobarometers: European Science and Technology 76/224/340	1992 2005 2010	13 024 24 896 26 671 (aged 15+)	Face-to-face interviews	Knowledge, interest, level of information, image of S&T, attitudes towards S&T, responsibilities of scientists and policy makers, scientific research, role of young people and women, trust in scientists, effectiveness of European scientific research
	Eurobarometer/Special Eurobarometer: Attitudes Towards Radioactive Waste 50.0/56.2/227/297	1998 2001 2005 2008	 16 029 24 708 26 746 (aged 15+)	Face-to-face interviews	Attitudes towards nuclear energy, attitudes and expectation regarding radioactive waste management, role of the EU in radioactive waste management, awareness and knowledge, sources of information

Context	Title	Years	No of respondents	Data collection	Topics
Europe	Special Eurobarometers: Attitudes of European Citizens towards the Environment 51.1/217/295/365/416/468	1999 2004 2007 2011 2014 2017	16 144 24 867 26 730 26 825 27 998 27 881 (aged 15+)	Face-to-face interviews	Attitudes towards the environment, information, impact of environmental issues, behaviour and priority, action to tackle environmental issues, EU and environmental protection, use of natural resources, specific topics such as ecolabels and air pollution
	Special Eurobarometer 203/Wave 60.2: Illegal and Harmful Content on the Internet	2003	16 059	Face-to-face interviews	Children's use of internet, parents' rules for their use, information on how to protect children from illegal or harmful content, awareness of how to report illegal and harmful content
	Special Eurobarometer 225/Wave 63.1: Social Values, Science and Technology	2005	32 897 (aged 15+)	Face-to-face interviews	Actors and decision-making in science and technology, the role of ethics, science and technology in the future of society
	Special Eurobarometer 282/Wave 67.2: Scientific Research in the Media	2007	26 717 (aged 15+)	Face-to-face interviews	Interest in scientific research, evaluation of the presence of scientific research in the media, preferences and expectations
	Flash Eurobarometer Attitudes towards Biodiversity 219/ 290 /379/436	2007 2010 2013 2015	25 080 27 129 25 537 27 718 (aged 15+)	Telephone interviews (landline and cell phone)	Understanding of biodiversity loss, informedness, biodiversity threats, biodiversity issues, protecting biodiversity, personal efforts, nature protection areas, information, awareness of Natura 2000 Network
	Special Eurobarometer Europeans' Attitudes towards Climate Change 300/313/372/409/459/490	2008 2009 2011 2013 2017 2019	30 170 30 232 26 840 27 919 27 901 27 655 (aged 15+)	Face-to-face interviews	Perceptions of climate change and global warming, information about climate change, combating climate change, citizens' involvement in fighting climate change/ individual action, attitudes towards fighting climate change, transitions to clean energy, renewable energy, etc.
	Flash Eurobarometer 316: Attitudes of Europeans towards Resource Efficiency	2011	27 164 (aged 15+)	Telephone interviews (landline and cell phone)	Use of natural resources, households' waste management, paying for waste management, food waste production, product's environmental impact, second hand products, products made of recycled materials

Context	Title	Years	No of respondents	Data collection	Topics
Europe	Flash Eurobarometer 367: Attitudes of Europeans towards Building the Single Market for Green Products	2012	26 573 (aged 15+)	Telephone interviews (landline and cell phone)	Behaviours and attitudes towards environmentally friendly products, influence of environmental considerations on consumption habits, actions for the environment, consumer confidence about environmental claims, sustainable consumption
	Flash Eurobarometer 360: Attitudes of Europeans towards Air Quality	2012	25 525 (aged 15+)	Telephone interviews (landline and cell phone)	Level of information, seriousness, changes over preceding 10 years, impacts on air quality, threats, energy production, role of different actors, tackling problems, EU legislation, respiratory problems
	Flash Eurobarometer 344: Attitudes of Europeans towards Water-related Issues	2012	25 524 (aged 15+)	Telephone interviews (landline and cell phone)	Level of information about water-related problems; seriousness of problems; changes in water quality; impact of various factors on water; main threats to the water environment; price of water; use of water; role of different actors; river basin management
	Flash Eurobarometer 361: Chemical	2012	25 557 (aged 15+)	Telephone interviews (landline and cell phone)	Awareness of chemical substances in everyday items, attitudes towards chemical substances, safety of chemical substances in the EU, responsibility for ensuring safety of chemical substances in the EU
	Special Eurobarometer: Cyber Security 290/404/423/464a	2012 2013 2014 2017	26 593 27 680 27 868 28 093 (aged 15+)	Face-to-face interviews	Overall perception of cybercrime as a threat to security, internet use, concerns about Internet transactions, knowledge, awareness and experience of cybercrimes
	Special Eurobarometer 401/Wave 6: Responsible Research and Innovation (RRI) Science and Technology	2013	27 563 (aged 15+)	Face-to-face interviews	Engagement with science and technology, impact of science and technology on society, attitudes towards science and technology, ethics and science, young people and science, gender issues and science, open access to research results
	Flash Eurobarometer 388: Attitudes of Europeans towards Waste Management and Resource Efficiency	2013	26 595 (aged 15+)	Telephone interviews (landline and cell phone)	Efficient use of resources, household waste – generation and management, plastic waste and litter, related attitudes and actions/ behaviour

Context	Title	Years	No of respondents	Data collection	Topics
Europe	Special Eurobarometer 419/Wave 6: Public Perceptions of Science, Research and Innovation	2014	27 910 (aged 15+)	Face-to-face interviews	Personal scientific background; priorities for science and technological innovation over the next 15 years; impact of society, science and technological innovation on different areas of activity
	Flash Eurobarometer 404: European Citizens' Digital Health Literacy	2014	26 566 (aged 15+)	Telephone interviews (landline and cell phone)	Use of the internet to search for health-related information, information searched for, satisfaction with the information found, alternative sources, health-related knowledge
	Special Eurobarometer 427/ Wave EB82.4: Autonomous Systems	2014	27 801	Face-to-face interviews	Attitudes towards robots, attitudes towards the future use of robots, acceptance of autonomous cars, attitudes towards the use of civil drones
	European Social Survey: Public Attitudes to Climate Change	2016	44 387	Face-to-face interviews	Beliefs on climate change, concerns about climate change and energy security, personal norms, efficacy and trust, and energy preferences
	European Perceptions of Climate Change (France, Germany, Norway, UK)	2016	1 000 in each country (aged 15+)	Face-to-face interviews (UK, Germany, France) Telephone interviews (Norway)	Perceptions of climate change (relevance, images, concern, beliefs, emotions, scientific consensus, science as solution, identity and efficacy), climate impacts, perceptions of energy-related issues (preferences, trust, energy production, individual energy use), policy support, climate change and migration
	Special Eurobarometer 460/ EB87.1: Attitudes towards the Impact of Digitisation and Automation on Daily Life	2017	27 901 (aged 15+)	Face-to-face interviews	Impact and use of digital technologies, digital skills, attitudes towards content on social networks, attitudes towards robotics and artificial intelligence, digital health and care, cyber security
	Special Eurobarometer 480/ EB90.2: Europeans' Attitudes towards Internet Security	2018	27 339 (aged 15+)	Face-to-face interviews	Internet use, concerns about internet interactions, awareness and experience of cybercrimes, fighting cybercrime, perceptions of institutions' responsibility to provide assistance to citizens for the different types of cybercrimes
France	*La Recherche* and *Le Monde* Climate Survey (Research and The World Climate Survey)	2015	1 053		Awareness, and understanding of climate change
Germany	*Wissenschaftsbarometer* (Science Barometer)	2014–2018	-1 000 each year	Telephone interviews	Interest and information, trust in science, science in society, attitudes

Context	Title	Years	No of respondents	Data collection	Topics
India	India Science Report: Science Education, Human Resources and Public Attitude towards Science and Technology	2005	30 000	Face-to-face interviews	Various knowledge and attitude items
Israel	Science and Technology in the Israeli Consciousness	2006	490 (aged 18+)	Telephone interviews	Attitudes towards S&T, trust in science institutions, prestige of science careers
	Perceptions and Attitudes of the Israeli Public about Science, Technology and Space	2016	501	Online (Hebrew); telephone interviews (Arabic)	Various knowledge and attitude items
Italy	Annuario scienza tecnologia e società (Technology and Society Science Yearbook)	2005–2019		Telephone and web-based interviews	Includes attitudes to science and technology
Japan	2001 Survey of Public Attitudes towards and Understanding of Science and Technology	2001	2 146	Face-to-face interviews	Various knowledge and attitude items
	Survey of Scientific Literacy	2011	812–984	Internet survey and interviews	Various knowledge items
Korea	Survey of Public Attitudes towards and Understanding of Science and Technology	2004 2006 2008 2012	-1 000 each year	Face-to-face interviews	Interest, various knowledge and attitude items, visits to informal science institutions
Malaysia	Public Awareness of Science, Technology and Innovation (STI) Malaysia	1994 1996 1998 2000 2002 2004 2014	5 000 5 055 5 000 5 000 9 760 6 896 2 653 (12–64 years)	Face-to-face interviews	Interest, awareness, various knowledge and attitude items, sources of information, involvement, visits to informal science institutions, STI related government programmes and policies, focus on specific issues such as nuclear power and climate change
Mexico	Encuesta sobre la percepción pública de la ciencia y la tecnología (Survey on Public Perception of Science and Technology)	2015	3 200 (older than 18)		Level of scientific culture, knowledge of basic S&T concepts and approaches to S&T processes, interest, attitudes towards S&T progress, willingness to support government spending on S&T, sources of information
New Zealand	Public Attitudes towards Science and Technology	2002 2005 2010 2014 2017	801 (telephone) 2 504 (online), 500 (telephone) 2 502 (online), 501 (telephone) (aged 15+)	An online survey Telephone survey with a CATI approach	Understanding of S&T, attitudes (feelings about S&T, interest in S&T, perceived Importance of S&T), behaviours relating to S&T (academic engagement, vent or attraction-based engagement, community-based engagement, work-based engagement, media engagement), S&T information

Context	Title	Years	No of respondents	Data collection	Topics
Russia	Russian Public Opinion on the Knowledge Economy	1995 1996 1997 1999 2003	2 392 2 404 2 322 2 431 2 107 (aged 16+)	Respondents filled in paper questionnaires in the presence of an interviewer	Various knowledge and attitude items, including interest, sources of information, S&T innovation, priority areas of research, consequences of S&T development; assessments of the contribution of S&T, scientific literacy
Spain	Percepción social de la ciencia y la tecnología (Social Perception of Science and Technology in Spain)	2002 2004 2006 2008 2010 2012 2014 2016 2018	3 088 3 400 6 998 7 367 7 744 7 744 6 355 6 357 5 200 (aged 15+)	Face-to-face interviews	Public's perception of S&T, including interest, attitudes, sources of information, scientific research, focus on specific S&T issues
Sweden	VA Barometer	2002, 2006–2019	-1 000 each year (aged 16–74)	Telephone interviews	Interest, confidence, attitudes, research, research as a career, science and society, technology, personal involvement
UK	Science and the Public: A Review of Science Communication and Public Attitudes to Science in Britain	2000	1 839	Qualitative study (16 group discussions) Quantitative study (-1 200 interviews)	Personal confidence in coping with change and new developments (attitude to life), perceived benefits of science, interest in science (attitude to science), trust in politicians and regulation
	Information and Attitudes: Consulting the Public about Biomedical Science	2000	696	Four stages: Face-to-face interviews; telephone interviews; group events/telephone interviews (videos); follow-up telephone interviews	Attitudes towards genetic technology, information
	Science in Society	2005	1 831 (aged 16+) Booster interviews with 417 adults from black and minority ethnic groups	Face-to-face interviews Qualitative research fed into questionnaire design	Attitudes to risks and benefits of science, informed about science and science education, involvement in science and engineering, science qualifications, views of scientists and science communication, trust in scientists, regulation of science, attitudes to the governance of science; involvement in consultation

Context	Title	Years	No of respondents	Data collection	Topics
UK	Public Attitudes to Science 2008	2008	1 000 members of the public 2 000 members of the public	Omnibus survey Six discussion groups with the general public Quantitative survey Six qualitative workshops with the general public	Interest; involvement; knowledge; communication and consultation; regulation; education and careers
	Wellcome Trust Monitor: Tracking Public Views on Medical Research	2009	1 179 adults (aged 18+) and 374 young people (aged 14–18)	Face-to-face using computer-assisted personal interviewing (CAPI)	Exposure to science; awareness and understanding of science and medical research; participation in, and engagement with, medical research; information sources; support, expectations and concerns; attitudes towards genetics, experiences and perceptions of science education, attitudes towards science as a career
	Wellcome Trust Monitor Wave 2: Tracking Public Views on Science, Biomedical Research and Science Education	2013 (conducted 2012)	1,396 adults (aged 18+) and 460 young people (aged 14–18)		Knowledge about science and medical research, interest in science and medical research; hopes and concerns about medical research; trust and governance; vaccination, nutrition and obesity, and cognitive enhancement; science at school; future careers
	Wellcome Trust Monitor Report Wave 3: Tracking Public Views on Science and Biomedical Research	2016 (conducted 2015)	1 524 adults		Knowledge, interest and engagement; value of science; cultural and informal science experiences; participation in medical research; 'healthy food'; antibiotics, alternative medicine
	Public Attitudes to Science (Ipsos MORI)	2011	2 103 UK adults (aged 16+)	Face-to-face interviews Four sets of e-workshops with the general public	Attitudes to science, scientists and science policy; interest; information sources; trust; regulating science; consultation and involvement; studying science and science as a career; science and the economy
	Public Attitudes to Science 2014 (Ipsos MORI)	2014	1 749 UK adults (aged 16+) and a booster survey of 315 16–24 year-olds	Face-to-face interviews Online qualitative research and social listening; follow-up face-to-face observational interviews with members of the online community Day of Discovery workshop with 106 members of the public	Attitudes to science, scientists and engineers; interest; information sources; science in a digital age; trust and confidence, involvement; studying science and science as a career; science and the economy; attitudes to big data, agri-science and food security, robots, emerging energy technologies

Context	Title	Years	No of respondents	Data collection	Topics
UK	Public Attitudes to Chemistry	2015	20 575 8 2 104 450	Telephone interviews Online surveys Workshops with 8–12 members of the public Face-to-face interviews Surveys with members of the Royal Society of Chemistry	Interest and engagement with science; attitudes towards science, scientists, chemistry, chemists, chemicals
USA	Science and Engineering Indicators (Includes a Chapter on Public Attitudes and Understanding)	1979–2018 (every 2 years)	Various sources	Range of methods, depending on the source	Information sources, interest, involvement, knowledge about S&T, attitudes about S&T in general, attitudes about specific S&T-related issues
	Various Surveys (Gallup Organization)	1982–2017	-1 000	Telephone interviews	Federal priorities, environmental protection, climate change, global warming, nuclear power, alternative energy, animal research, stem cell research, quality of science and mathematics education in U.S. public schools – attitudes
	Media and Political Surveys (Various) (Pew Research Center for the People and the Press)	1985–2016	1 000 – 5 122	Telephone interviews	Information sources, Internet use, national policy attitudes (environment, global warming, energy, stem cell research), government spending for scientific research attitudes, views of the news media, media believability
	Biennial News Consumption Survey	1996–2008	3 615 (2008)	RDD	Information sources, interest
	Virginia Commonwealth University (VCU) Life Sciences Survey	2001–2008	-1 000	RDD	S&T interest, general attitudes, stem cell research and animal research attitudes
	General Social Survey (GSS) S&T Module	2006 – 2016 (every two years)	1 864–2 256	Face-to-face interviews, supplemented by telephone interviews	Information sources, interest, visits to informal science institutions, general attitudes, government spending attitudes, science and mathematics education attitudes, animal research attitudes, nanotechnology awareness and attitudes, science knowledge
	Climate Change in the American Mind	2008, 2010–2019 (twice a year)	1 010–2 164	Online	Attitudes to climate change/ global warming, beliefs, emotional responses, perceived risks, engagement, efficacy beliefs

Context	Title	Years	No of respondents	Data collection	Topics
USA	National Surveys on Energy and Environment	2008–2019	603–988	Telephone interviews	Topics such as public policy approaches to address climate change, international action; energy policies, carbon taxes, renewable energy requirements, vehicle emissions standards, knowledge and attitudes about global warming, climate adaptation, fracking, and geoengineering
	General Public Science Survey, Separate Survey of American Association for the Advancement of Science Members	2014	Public: 2 002 Scientists: 3 478	Telephone interviews (survey of general public)	Public's and scientists' beliefs about S&T-related issues, quality of STEM at school, benefits of science to well-being of society, focus on specific topics such as animal research, genetically modified food, and energy
Various countries	Programme for International Student Assessment (PISA)	2000–2018 (every three years)	Around 500 000 learners across countries each round	Paper-based tests Computer-based assessments in some countries	Literacy (rotation of mathematics, science and reading), learner attitudes (such as engagement, motivation for learning, self-beliefs)
Various countries	Relevance of Science Education (ROSE)			Paper-based tests	S&T-related out-of-school experiences; interests in learning different S&T topics; prior experiences with and views on school science; views and attitudes to science and scientists in society; future hopes, priorities and aspirations
Austria, Czech Republic, Germany, Denmark, Spain, France, Ireland, Italy, Netherlands, Poland, UK, Sweden, US, Japan, Israel	BBVA Foundation International Study on Attitudes Towards Stem Cell Research and Hybrid Embryos	2007/2008	1 500 in each of 15 countries (-22 500 in total)	Face-to-face interviews	Awareness and understanding, perception of medical benefits, fears and reservations, use of embryos to obtain stem cells, acceptance of stem cell research, creation of hybrid embryos to obtain stem cells, preference for regulatory level
Italy, Spain, Austria, Czech Republic, Poland, Germany, the Netherlands, France, UK, Denmark, USA	BBVA Foundation International Study on Scientific Culture	2011	1 500 in each of 11 countries (aged 18+)	Face-to-face interviews	General attitudes towards science; expectations about science, focusing on specific scientific areas and applications; evaluation of inventions of the modern age; science, ethics and religion; support for basic science funding; image of the scientist and trust in scientists; image of the scientific career

Context	Title	Years	No of respondents	Data collection	Topics
Czechia, Germany, Italy, Spain, Sweden, UK	Public Attitudes to Life Sciences Research in Six European Countries	2018	5 870	CATI conducted on six nationally representative samples of respondents chosen by RDD	Interest in, and confidence about, life sciences research; personal involvement in life sciences research; genome editing – awareness and concerns
Over 140 countries, including South Africa	Wellcome Global Monitor: How Does the World Feel about Science and Health?	2018	>140 000 (aged 15+)	Face-to-face interviews	Trust in science, scientists, and information about health, the levels of understanding and interest in science and health, the benefits of science, the compatibility of religion and science, and attitudes to vaccines
Canada, France, Germany, Japan, Singapore, UK, US Brazil, China, India, Mexico, Poland, Saudi Arabia, South Africa	3M State of Science Index Global Report	2018	14 036 adults (aged 18+) Sub-set (345 globally) of key business decision influencers)	15-minute survey, combination offline and online	Image of science (e.g. importance of scientific knowledge, own knowledge, confidence in own knowledge, interest and curiosity, science careers and skills) Impact of science (e.g. sources of information, view of scientists, science communication, artificial/ virtual connections, science innovation/advancements) Expectations of science (e.g. role of science in solving global problems, issues science can solve, expected solutions, barriers to future advancements, scepticism and trust in science, value of science, personal involvement, importance of science to aspects of life)
Canada, Germany, Japan, Singapore, South Korea, Spain, UK, US, Brazil, China, India, Mexico, Poland, South Africa		2019	14 025 adults (aged 18+)		

APPENDIX B: SOUTH AFRICAN SURVEYS ON THE PUBLIC RELATIONSHIP WITH SCIENCE

Organisation/ Author	Title	Year	No of respondents	Data collection	Topics
Pouris	Understanding and Appreciation of Science among the Public in South Africa	1991	1300	Face-to-face interviews in six suburbs	Knowledge of physics and earth sciences facts, beliefs about human origins, public attitudes towards astrology, beliefs related to the effects of science in everyday
Pouris	Understanding and Appreciation of Science among South African Teenagers	1993	800	Face-to-face interviews in suburbs	Knowledge, attitudes and beliefs regarding S&T
Pouris	Interests, Public Attitudes and Sources of Scientific Information in South Africa	2001	1000 households	Face-to-face interviews in metropolitan areas	Interest in selected issues; attitudes towards science and technology, sources of information used by citizens
Pouris	Assessing Public Support for Biotechnology in South Africa	2004	1000 households	Face-to-face interviews in consumer survey	Trust in S&T, opinions of biotechnology, knowledge of the field, predisposition of the media towards science
FRD–HSRC	SA Science and Technology Indicators – Public Understanding of Science Chapter	1995	2 163	Three surveys measuring scientific knowledge, attitudes to Science and a survey on Human Science Literacy	Natural and environmental factual knowledge, attitudes toward science, human sciences literacy
Foundation for Research and Development (FRD) and HSRC (Blankley & Arnold)	Public Understanding of Science in South Africa – Aiming for Better Intervention Strategies	1999	2 207 (aged 18+)	Face-to-face interviews in major metropolitan areas	Studying science at school, attitudes to science and technology (promise-reservation), levels of interest
HSRC	Omnibus Survey	1995	2 200 (aged 18+)	Face-to-face interviews	Attitudes, beliefs, values and behaviour patterns
HSRC	Evaluation of Public Opinion (EPOP) Survey	1999		Face-to-face interviews in household survey	Importance of mathematics, science and technology; attitudes towards S&T (promise–reservation index); balance between the benefits and harms of scientific research
Goolam	The Scientific and Technological Literacy of First-Year Physics Students: the Effects of a Traditional School Curriculum	2001	171 students in 1st year of Physics Programme at University of Pretoria	Mixed methodology survey	Scientific and technological literacy

Organisation/ Author	Title	Year	No of respondents	Data collection	Topics
HSRC	SASAS Biotechnology Survey	2003 2014	7000 2 940 (aged 16+)	Face-to-face interviews in household surveys	Knowledge of biotechnology, genetic engineering, genetic modification, cloning, new technologies, uses of biotechnology, acceptance of biotechnology
HSRC	SASAS Environment	2004 2010 2013	2 799 3 112 2 739 (aged 16+)	Face-to-face interviews in household surveys	State of the environment, pollution, genetic modification, governmental involvement, environmental issues, people vs environment, responsibility for protecting the environment, costs of environmental protection
HSRC	SASAS Climate Change/Global Warming	2007 2017	3164 3 098 (aged 16+)	Face-to-face interviews in household surveys	Knowledge and concern about climate change, causes and impacts, responsibility for prevention, government involvement
HSRC	SASAS Indigenous Knowledge	2009	3 307 (aged 16+)	Face-to-face interviews in household surveys	Opinion of indigenous knowledge, government promotion of indigenous knowledge, roles in indigenous knowledge, sources of information
HSRC	SASAS Public Relationship with Science	2010 2013	3 183 3 057 (aged 16+)	Face-to-face interviews in household surveys	Promise reservation index, sources of information, science knowledge, science at school and as a career, interest in S&T developments, science centres and museums
HSRC	SASAS Energy	2011 2012 2013 2017 2018	3 004 2 518 2 739 3 098 2 736 (aged 16+)	Face-to-face interviews in household surveys	Energy sources, expenditure, needs, electricity-quality and cost, ways to save energy, electricity provision
HSRC	SASAS Nuclear Energy/Technology	2011 2013	3 004 3 057 (aged 16+)	Face-to-face interviews in household surveys	Knowledge of, benefits of, concerns about, uses of, risks of, role of nuclear energy; role of government; sources of information
HSRC	SASAS Astronomy and SKA	2013	3 057 (aged 16+)	Face-to-face interviews in household surveys	Attitudes to astronomy, knowledge of and attitudes about the Square Kilometre Array (SKA) Telescope
HSRC	SASAS 4IR	2018	2 736 (aged 16+)	Face-to-face interviews in household surveys	Promise reservation index, knowledge, skills, attitudes towards new technologies

Organisation/ Author	Title	Year	No of respondents	Data collection	Topics
IPSOS	World Values Survey	1981 1990–1991 1995–1996 1999–2001 2005–2006 2010–2014 (Waves)	Number varies 3 531 in SA in 2013	Face-to-face interviews in household surveys Face-to-face interviews, mail or online surveys (depending on country)	Promise-reservation of science, faith, environmental and economic attitudes
Afro-barometer (Climate change)	Afrobarometer (Various African Countries, Including SA)	2016–2018	45 823	Face-to-face interviews	Knowledge of climate change, attitudes to climate change, causes and effects of climate change, agency
Parker	Development of Indicators for the Measurement of the South African Publics' Relationship with Science	2017	3 486	National household survey using face-to-face interviews	Public knowledge (9 items), public attitudes toward science (Promise and Reservation index), interest in science (7 selected areas of science), sources of scientific information and frequency of access, attendance at engagement activities
Laugksch	Test for Scientific Literacy and its Application in Assessing Scientific Literacy of Matriculants Entering Universities and Technikons	1996	4 277	Questionnaires for first-year students in Western Cape tertiary institutions	Scientific literacy – including questions on the nature of science, science content knowledge, and the impact of science and technology on society.
IEA	Trends in International Mathematics and Science Study (TIMSS)	1995	5 267 Grade 7 learners 4 413 Grade 8 learners 3 757 Grade 12 learners	Paper and pencil tests,[4] and background questionnaires	Mathematics and science knowledge, attitudes to mathematics and science (interest, value, confidence)
		1999	8 147 Grade 8 learners		
		2003	8952 Grade 8 learners 4 261 Grade 9 learners		
		2011	10 085 Grade 9 learners		
		2015	10 932 Grade 5 learners 12 514 Grade 9 learners		
		2019	11 955 Grade 5 learners 20 880 Grade 9 learners		

Adapted from HSRC (2009); Parker (2017)

26 In 2019, e-TIMSS were introduced in some countries. South Africa however continued with paper and pencil tests.

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