Exploring the Cultural Authority of Science in South Africa through Public Attitudes to Science (2015-2016)

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INTRODUCTION

Thomas Huxley is now famously chronicled as initiating debates about the value and importance of science to the culture of humanity and its importance within a modern economy (Miller, 1983). The cultural authority of science has evolved and shifted since the late 19th century, however, more than 130 years later, despite radical advances in science and technology, the authority, importance and culture of science remains an ongoing debate within the polemic. Counter to the contemporary broad public perception, science is neither a qualification nor a career path. We are reminded of what science *is*: a systematic way of thinking about the world, about building knowledge and more importantly explaining phenomena through testing observations and assembling an iterative consensus of how the universe works. These are the elemental foundations of the *scientific method* that lead to replicability, reliability and accuracy within research outputs.

Yet despite this, it is often overlooked that science is essentially a social enterprise, wherein agreement among the community of practice legitimises the findings and evidence presented. What has been emerging over the last 60 years is that the general public has a definite role to play within this community of practice, driving innovations and building support for research funding through social advocacy and two-way engagement practices. While the *culture of science* and *science culture*, relate to different focus areas, Shukla and Bauer (2009) note these *"are two sides of the same coin …"* that requires a detailed understanding toward promoting the ideals of the entire scientific enterprise.

This realisation then raises the question of what the cultural authority of science represents in different social settings. The *scientific enterprise* and *public perceptions of science* are often related and as a result introduces a *human factor* outside of the ivory towers of scientific labs, which necessitates a deeper look at the *culture of science* within locally relevant public perception data streams.

A *scientific mind-set* requires a sense of *healthy scepticism, suspended judgement and disciplined eclecticism*, with well executed projects more often stimulating further questions, than definitive answers. This sense then, of the iterative nature of science, produces a body of knowledge that is continuously incomplete, ever-changing and evolving. To the general public this erodes a sense of trust invested in the authority of scientists and scientific institutions. This may lead to a public, resistant to scientific evidence or at best, considering scientific knowledge *static* rather than the *dynamic* body of knowledge it needs to be.

In a contemporary world, the influence of science on the public, and indeed the more important influence of the public on science are clearly evident. Key examples here remain early childhood vaccination, GMO foods, nuclear power and climate change, where significant social and policy changes were considered as a result of public perceptions related to advances in these areas. The significant influence of mobile technology and the influence and reach of "fake news" via social and mainstream media facilitates a culture wherein citizens are prone to resist scientific claims when they clash with intuitive belief or knowledge ecosystems. Despite increasing education levels, the public's trust in the scientific community has been decreasing and remains inadequate (Gauchat, 2010**)**. This mistrust essentially led to the development of the early models of scientific literacy and public understanding of science research in Europe and the USA.

Within the South African context, the public is in many respects fragmented by varying social influences and as a result, the South African public may be viewed as a number of public's, rather than a single homogenous public. To this end the study of the public's understanding of science, becomes increasingly important toward developing an awareness of the social dynamics of public trust in science. Measurement metrics and indicators then become a *sine qua non* within the study of science and human culture.

Recent empirical data streams from within the South African population lends itself well to exploring where these dynamics may manifest toward understanding the cultural authority of science in South Africa. However, before one is able to make sense of the data outputs, an appreciation of the historical and cultural milieu of the South African population becomes increasingly important within which to contextualise the South African public understanding of science.

THE STATE and SCIENCE IN SOUTH AFRICA

South Africa has a chequered history in recounting its association with science and its influence on society. Mouton *et al* (2001) present a brief history of science in South Africa identifying five key periods that saw the development and formalisation of many of the elements we see today in the South African National System of Innovation. These five periods include the *Colonial era* (1751 – 1880); *Industrial era* (1880 – 1910); *War Time Science in South Africa* (1910 – 1948); *Apartheid Era Science* (1948 – 1994) and the *Post-Apartheid scientific system* (1994 – present). Each of these periods is bookmarked with key developments and societal dynamics that changed the context and direction of the scientific enterprise moving forward. The context of history remains pivotal to understating South African society, as well as its impact on the contemporary culture and authority of science.

During the colonial era (1751 – 1880) many European scientific communities saw the new territory at the Southern tip of Africa with keen scientific interest. Astronomy, botany, zoology, military science, geology and engineering all benefitted the European settlers politically, commercially and in terms of developing basic local infrastructure. The early 1800's saw a growing scientific community and some of the first scientific institutions in South Africa. These include the Royal Observatory in 1820, The Royal Society in the late 1820s and the South African Museum in 1825 (Mouton & Geevers, 2009). Many of these institutions are still active today and continue to contribute significantly within their respective disciplines. This model of colonial era science is reflected across the continent and is deeply connected with science and exploration. These early scientific institutions had from the beginning seen a certain degree of political sway, as much of South African history, even scientific and educational history is infused with clear notes of political influence and colonial ideology.

The discovery of mineral wealth established the link between industrialisation, science, technology and development[1]. Gold and diamonds catapulted the arrival of foreign mining, geological, geographical, chemical and engineering personnel to drive the required fields of science within the growing South African economy. Employment in the sciences was finally a reality in South Africa (Mouton *et al*, 2001).

Beyond the economic and engineering opportunities, the rapid industrialisation led to increased concentration of human settlement, bringing with it serious public health concerns related to sanitation, overcrowding and poor planning. The establishment of the Onderstepoort Veterinary Institute in 1908 (MRC, 2001; ARC, 2011), and the South African Institute for Medical Research in 1912 (Murrey, 1963; MRC, 2001) responded to the growing needs of early boom towns. The economy, still highly dependent on domestic agriculture, saw the growing need for agricultural research, with threats such as the tsetse fly, rinderpest and bilharzia not only decimating animal stocks but also proving to be serious threats to human health (MRC, 2001). It has been argued that one of the foremost reasons for the establishment of the South African Institute for Medical Research (SAIMR, later the MRC) was due to the high incidence of serious illness among African[2] mine workers (MRC, 2001). The establishment of these institutions allude to motivational reasons serving an economic need rather than the more obvious social health imperative of the time. Following the formation of the Union of South Africa (1910-1961) the involvement in World War 1 led directly the first South African Science and Technology Planning Framework in 1916 (Scerri,

[1] In 1876 the first telegraph communication lines between Cape Town and Kimberly were established, supporting the diamond mining boom of the 1860's (Perkins *et al*, 2005).

[2] A term often used to describe native Black South Africans

2008). This framework served the purpose of directing resource optimisation and the development of state companies and resources within this period in South Africa (Scerri, 2008; Mouton & Geevers, 2009)[3].

With the institutionalisation of apartheid[4] in 1948, the eventual political isolation of South Africa under sanctions saw the next era for science (1948-1994). During this time, despite the global isolation, domestic scientists managed to produce promising research, particularly in the defence, energy and nuclear sectors. South Africa in this time successfully developed six nuclear weapons (Pike, 2011, Albright, 1994), and began successfully implementing mass industrial technology for coal-to-fuel synthesis (Sasol, 2005). This was a period of dramatic growth for the South African science system. However due to the influence of apartheid, many of the brightest South African scholars opted to leave the country and contributed significantly to the brain drain experienced in the late 1980's (Crush et al, 2005, Ndulu, 2004, Bhorat et al, 2002). This exodus further impacted South Africa's contemporary and future science and technology development.

The influence of these various periods within the development of the South African science system are integrally related to educational resources and outputs during this time. Particularly instrumental was the impact of segregated education under *apartheid era* educational policies, principally within the majority Black / African population. Laugksch (1996) develops a picture of education under the various apartheid laws where prior to 1948 there had been no coherent educational policy active in South Africa. However, subsequent to this there was a deliberate policy toward limiting the educational attainment standards of non-white[5] citizens that would set the tone of racially-based education over the next 50 years. These educational policies further impacted the number of non-white students completing the school-leaving examinations (grade 12), required for university enrolment and continue to impact graduate outputs in contemporary South Africa.

Following the first democratic elections in 1994, South Africa began driving science and education policy initiatives to foster a new generation of educated youth to drive the development of a more inclusive national scientific system. The democratic government actively pursued this goal through various investment, educational, and social projects in order to build a national system of innovation (NSI). However, the marked shortage of a suitably qualified human resource capital within the

[3] These include the *Electricity Supply Commission* (ESKOM), *The Iron and Steel Corporation* (ISCOR), the *Industrial Development Corporation* (IDC) and one of the contemporary science councils – the *Council for Scientific and Industrial Research* (CSIR).
[4] A system of institutionalised racial segregation and discrimination in South Africa between 1948 and 1991.
[5] A term often used to describe South Africans of non-European / Caucasian ancestry

country was a bottleneck to the effective growth of a knowledge economy. Ellis (2001) notes that South Africa in the 21st century will be part of a global science system...*however, it will be unlikely that South Africa may become a great power in the global knowledge economy*…if this skills gap is not effectively addressed. Since the late 1990's the OECD in particular has lauded government efforts toward improving education policy and resources mobilisation in attempting to address the issues of human capital shortages (OECD, 2007) which remains key to driving a human resource development strategy within a knowledge economy context (Kaplan, 2008b).

In present-day South Africa, a country of 51.7 million people (StatsSA, 2012), there exists a stark contrast in the levels of inequalities among its population. South Africa is home to an increasingly diverse population, apparent not only in the many cultures, traditions, languages and religions but also with regards to related concerns of access to education; income-distribution; basic services and employment as a result of the legacy impact of apartheid. Large proportions of the South African public still remain disenfranchised socially and marginalised economically, leading to an entrenched sense of inequality within the population. When exploring the public understanding of science in South Africa, broad-based inequalities have led to a highly stratified society (van der Berg, 2010). Reddy *et al* (2009) propose that it may be analytically useful to refer to the many strata of the South African populous as the *public**S***, accounting for the vast social disparities that exist and reflecting the heterogeneity within the population. The results of the 2011 South African National Census indicate that a considerably higher number of non-white learners now have access to free basic education, as well as onward higher and tertiary education than during the pre-1994 era. Notwithstanding this, 2011 Census further highlights only 28.9% of the total population completed Grade 12 schooling. Among these school-leavers, only 8.3% of Africans, 7.4% of Coloured, 21.6% of Indians and 36.5% of White learners continued on to enrol for a tertiary educational qualification.

Despite the 23 years since the end of apartheid, the legacy impact of apartheid across social stratifications is still apparent and is salient to understanding the multifaceted nature of South African society. The legacy impacts of apartheid are reflective within similar analysis for *income* and *employment* and exert a similar, yet interlinked influence on overall quality of life for the majority of South Africans. These factors combined have influenced the South African public understanding of science and may be shown to have linked influences on the overall cultural authority of science in South Africa.

Young people in Africa represent a significant portion of the population, in some regions as many as 60% (Aiwuyor, 2011, Ighobor, 2013). As these youth populations mature and enter the workforce, it is expected that the growing economies and increasing supply of labour will accelerate development and productivity across the region. The median age within the Chinese population is 34.5 years old however; the median age for African populations is 19.1 years old. As the populations of the current industrialised nations like USA, China and Japan age, the demand for labour will inevitably shift toward African economies (Indiwe, 2012). The growth in technology sectors, such as wireless ICT and mobile financial services has tremendously impacted the development across the diverse African regions. Linked to this is the vast number of young people capitalising on technological leaps, developing promising careers and entrepreneurial ventures based on the promise of the 4th industrial revolution (Gedye, 2012). These opportunities are still only accessible to a limited number of young people due to the current infrastructural constraints that exist across the African continent, including South Africa. However, as investment grows training and skills development would be paramount to capitalise on these on-going opportunities.

Research within the area of scientific literacy and the public understanding of science has only been a feature within the South African landscape for about 40 years. Much of this early work adopted Miller's *three consecutive dimensions* of scientific literacy, and is likely the entry point of this term into the general discourse among researchers aligned to the education community in South Africa. The focus of scientific literacy and the public understanding of science in South Africa had as its general aim, social advancement and economic development. Laugksch (1996) notes three aims of pursuing scientific literacy in South Africa, including an *economic* argument, *decision making* argument and a *democratic* argument.

Under the economic argument Laugksch notes the requirement of a competent human resource pool to develop and sustain the NSI. Within the *decision making* argument, citizens are required to have a certain level of proficiency in areas involving science and technology so that effective decision making may follow from within knowledge driven evaluation processes. This is particularly important in financial decisions, selection of appropriate health related interventions, environmental sustainability as well as civic responsibilities and its impact on public policy. The third argument relates to democracy building and social development in South Africa. Public knowledge and literacy are key to enabling individuals to make effective decisions related to governance and democracy. The importance of these three arguments for advancing scientific literacy is valid in contemporary South Africa as it was in 1996, and remains the foundational arguments within this paper.

Over the preceding 40 years a large, yet dispersed body of research exists within the South African public understanding of science research context. Within this unique social, economic, political and historic context, the diverse and varied interest's capabilities and competencies within the South

African population would present interesting findings in surveys of public understanding of science. The next section unpacks selected findings from the most recent nationally representative survey of South Africans public understanding of science.

DEVELOPMENT OF MEASUREMENT INDICATORS and HEADLINE RESULTS

In South Africa, too few appropriately designed public understanding of science studies[6], both in terms of size and scope, are conducted (see: Pouris, 1991 & 1993; Laugksch, 1996; HSRC, 1995, 1999; Blankley and Arnold, 2001; Reddy *et al*, 2009). While there have been more than 20 empirical studies conducted in South Africa since 1991, many have been limited to either *specific* areas of interest, or presented limited analytical agility. Data presented here is drawn from a nationally representative study conducted between 2015 and 2016 investigating the South African public understanding of science. The study employed a survey methodology, surveying respondents from all regions in South Africa[7] (n=3 486). The study developed 6 indicators, each characterising a facet of the adopted definition of the South African public understanding of science. This definition included the following elements: *knowledge* of science; *attitudes* to science; *interest* and *informedness* about science; science *information sources*; and attendance at *science engagement activities*. Each of the six elements have been operationalised using question designs reflective of the large surveys of PUS and *scientific literacy* (see: NSF / *EuroBarometer*), however specifically adapted[8] to the South African context.

The S*cience Knowledge* assessment included 9 statements[9] requiring a *True*, *False* or *Don't Know* response (e.g. *In the majority of cases, HIV causes AIDS in humans*). In order to localise the *knowledge* assessment with actual South African self-reported science *interest* areas, item-subject categories were constructed to match reported *interest areas* from earlier South African studies for the period 2001 – 2010. The *science knowledge* subject area categories selected includes *physical science* – astronomy & earth science; *biology* - medical science; *social science* – economics, mental health & history as well as a *multidisciplinary* area of information & communication technology.

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

[6] Sample size and coverage as well as limited population of measurement (students or particular race groups only)
[7] Urban and Rural, all gender, ethnic, language, income, education and other demographic based groups are represented.
[8] Where required, specific content, scientific subjects and information sources that were most relevant to the South African context were integrated.
[9] Knowledge items scientifically correct response: AIDS in humans (67.4%); Human genetics (46.6%); Plate Tectonics (46.2%); Climate change (41.7%); Nuclear weapons (39.5%); Economics (35.5%); Physical Science (32.7%); Astronomy (28.4%); Mental Health (24.4%)

specific positive or negative attitudes toward science requiring an *Agree*, *Disagree* or *Don't Know* response. The calculation procedure of the *Index of Promise & Reservation* is well documented in earlier research (see: Blankley & Arnold, 1999; Reddy *et al*, 2009; 2013).

Informedness[10] *and Interest*[11] in science was operationalised through using 7 topical areas of science. The levels of interest ranged from *Interested* to *Not Interested* and included a *Don't Know* response option. These science areas were determined through appropriate study of information sources in South Africa (e.g.: media analysis etc.) with the same focus on localisation as with the *knowledge* measures.

Items on S*cience information sources* were designed adopting 11 information channels[12]. Response indicated both a count of science information channels accessed as well as the frequency of exposure, allowing this study to formulate an *Information Emersion index*.

The last element was designed to assess the level of involvement in and exposure to *science engagement activities*. These engagement activities included visits to *public libraries* (19.8%), *zoos* (13.1%), *museums* (10.5%), *science centres* (7.2%), *public talks* and *festivals* (6.9%). Respondents were required to indicate if they had visited any of the listed locations within the preceding 12 months (*Yes* or *No*).

These six elements of the South African public understanding of science were cross-analysed with the corresponding demographic data toward the development of indicators. Headline results from within each of the 6 elements are briefly discussed in the below sections, along with the 6 indicators developed, prior to a discussion of the correlation relationships between these indicators.

KNOWLEDGE INDEX

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

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[10] Informedness in science items and overall ranking: Technology & the Internet (53.6%); Politics (52.0%); Economics (47.3%); Climate Change (46.8%); Energy (43.2%); Medical Science (43.0%); Astronomy (30.9%)

[11] Interest in science items and overall ranking: Technology & the Internet (64.5%); Climate Change (59.9%); Economics (59.2%); Energy (56.8%); Medical Science (56.4%); Politics (52.0%); Astronomy (40.1%)

[12] Science information sources overall ranking: Radio (86.3%); Newspapers (82.8%); Free-to-Air Television (82.5%); Other people (78.8%); Books / Magazines (75.3%); Satellite Pay Television (71.6%); Government Announcements (69.9%); Social media (68.2%); News Websites (65.6%); Institutional Websites (64.3%); Blogs (63.6%)

subject areas included within this study. This is lower when compared to an average of 65% within the USA population (NSF - S&E indicators, 2014) and levels within the European community (Eurobarometer series), however for the South African result this may be reflective of the overall levels of educational exposure and affinity to science within the general population. The overall national result for the *Science Knowledge Index* indicates that 37.0% of the sample was classified as being within the *low scientific knowledge* category; 27.3% were classified as having *moderate scientific knowledge*; while 35.7% were classified within the high scientific knowledge classification (See panel 1).

ATTITUDE INDEX

South Africans display an overall positive attitude toward science. In general 70.3% of South Africans agreed with *scientific promise* items, while there was a moderate level of agreement (58.1%) within the *scientific reservation* items. The general positive attitudinal position is an encouraging output and highlights a strategic benefit toward targeted science communication and the general public understanding of science. The ratio obtained by the entire South African population between the *index of scientific promise* and *scientific reservation* was 1.21, which conforms to previous studies conducted in South Africa producing this index.

National results within the *Index of Attitudes to Science* indicates that 44.1% of South Africans presented a generally more positive attitude to science across the 4 questionnaire statements, while 19.4% presented a generally more negative attitudinal position. Despite this overall positive result, at a national level, 36.5% of respondents presented a degree of attitudinal ambivalence, thereby producing no clear attitudinal direction in their responses (See panel 1). Ambivalent attitudes are less desirable than either positive or negative positions as they are inherently more malleable in the face of new informational inputs.

INTEREST INDEX

Within the 2015 study, 55.6% of South Africans declared a higher level of interest across the 7 scientific areas[13]. This comprised of 22.6% indicating high interest while 33.0% provided a *moderately interested* response. Overall 44.4% of the sample declared *no interest* across all questionnaire items (See panel 1). This average level of interest among South Africans is a positive result, indicating a greater curiosity about science in the population.

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[13] Interest and Informedness Index scientific areas: Technology & the Internet; Politics; Economics; Climate Change; Energy; Medical Science; Astronomy

The *index of interest in science* reveals an overall even distribution across the three *interest in science* outcome categories.

The result remains a positive outcome as not all members of society will intrinsically exhibit a high level of interest in science, and this should not be an expectation on all citizens. However, it is interesting to note that 75.7% of respondents indicated a *moderate* to *high* level of interest in science areas, a further positive outcome. Falk, *et al* (2007) demonstrated the importance of lifelong learning and the central influence *interest* and *curiosity* exerts over information acquisition and understanding of science. Thus, within a practical and policy context, *interest* in science remains an important factor in motivating knowledge seeking behaviour and ultimately understanding the cultural authority of science in South Africa.

INFORMEDNESS INDEX

Compared to the level of interest, fewer respondents report being adequately informed within the areas of science included[14]. An average of 45.3% of the sample report being adequately informed within all the scientific areas. This includes 14.3% that indicate they are *very well informed* while 30.5% indicate a *moderate* level of informedness (See panel 1). This is not an unexpected result as *informedness* usually lags *interest* in numerous studies of this nature. The *Index of Informedness about Science* reveals a similar trend to that of the *interest in science* index. Response within the *high* informedness category was marginally higher, however, overall there is an even spread in response.

INFORMATION IMMERSION INDEX

Sources of scientific information were assessed using an 11-item question set containing various channels of information[15]. South Africans encounter scientific information most frequently via the *radio* (86.3%); followed by *newspapers* (82.8%), *free-to-air television* (82.5%) and through contact with *other people* (78.8%). The media types least frequently selected as sources of scientific information were all within the *online* channels[16]. Much of which may be attributed directly to access to information sources, related to affordability and infrastructure, especially within a developing world context.

[14] See previous note.

[15] Information immersion was considered to be a combination of increased frequency encountering science information as well as number of information sources accessed

[16] These were ranked as follows: social media (68.2%); news websites (65.6%); institutional websites (64.3%) and blogs (63.6%).

A marginally larger share of respondents were classified as having a *high science information immersion* (35.0%), while 31.6% report a *moderate* level and 33.4% display a propensity toward a *low* science *information immersion* classification (See panel 1).

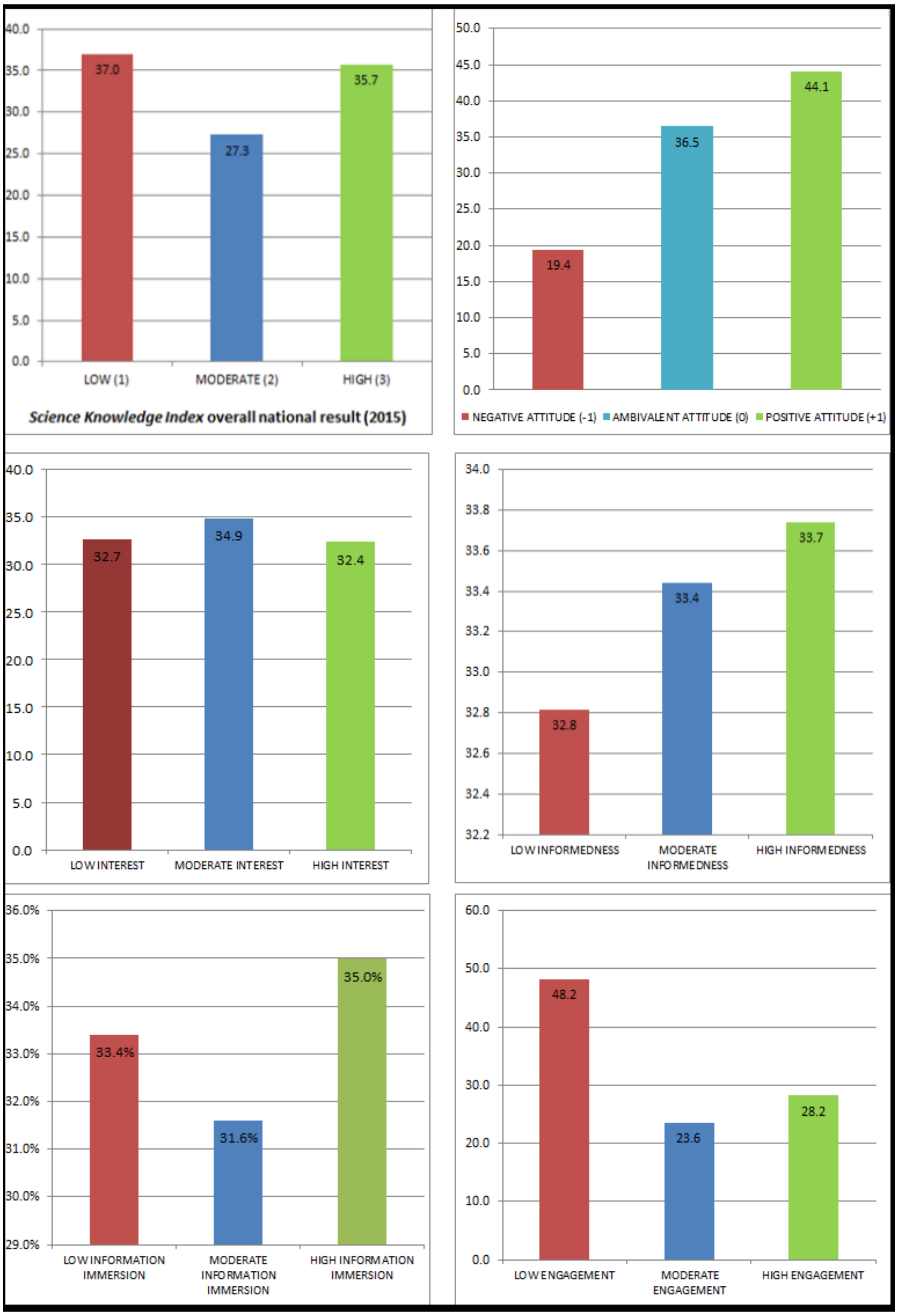
Within the *high information immersion* group 77.8% of respondents report encountering science information from between 6 and 8 different channels *most frequently*. Among those within the *moderate information immersion* group, 53.1% of those individuals report an average of between 5 and 6 science information channels with a frequency ranging between *occasionally* and *most frequently*. By contrast, in the *low information immersion* group 58.7% within this classification report encountering science information from between 2 or 3 information channels *least frequently* or *occasionally*.

ENGAGEMENT INDEX

Among the most important findings within this research is the level of science engagement, where only 11.5% of the survey sample (n = 3 486) report having visited any of the five science engagement locations listed. The vast majority of respondents (88.5%) report not having attended a science engagement activity within the preceding 12 months. The most frequently visited science engagement activity was *public libraries* followed by a *zoo or aquarium* and a *museum* (See panel 1). The selection options for *science centre, technology exhibitions* and *science café's, festivals or similar public event* received the lowest proportional response across all demographic classifications. The largest proportion of *Yes* responders report having attended one (1) type of engagement activity, with fewer respondents having visited two or three science engagement locations within the preceding 12 months.

All the indicators developed have undergone detailed quality, Item difficulty, item discrimination and reliability assessments procedures required toward validating the production of new indicators.

The six indicators represent a significant contribution to ongoing measurement efforts within the knowledge economy space in South Africa. This approach offers a starting point from within which to map a culture of science as well as gain a deeper understanding of the artefacts that exist within the Science-Public space in South Africa. In order to begin to map these relationships between the indicators, further analysis was conducted, toward mapping a culture of science.



Panel 1: Index outputs: SA Public Understanding of Science

	Factor Analysis				Cronbach's Alpha
Question set	KMO	Bartlett's Test of Sphericity	Eigenvalue	% of variance explained	Alpha
Science knowledge	0.934	p < 0.001	5.271	53.486	0.911
Attitudes to Science	0.838	p < 0.001	3.114	71.214	0.939
Interest in Science	0.938	p < 0.001	5.080	68.118	0.936
Informedness in Science	0.940	p < 0.001	5.371	73.022	0.949
Science Information Sources	0.947	p < 0.001	7.156	69.398	0.946
Science Engagement	0.899	p < 0.001	4.080	77.047	0.943

Table 1: Result of factor analysis and reliability assessment

RELATIONSHIPS BETWEEN INDICATORS

The six indicators developed reveal an interesting picture of the various elements of the public understanding of science in South Africa. This is particularly important in light of the historic context and its relative impact on the general public understanding of science. Demographic and social inequalities that perpetuate in South Africa continue to impact the development agenda – how then does this influence the cultural authority of science?

An assessment was conducted to investigate the strength and direction of relationships that exist between the indicators developed. While there remains a theoretical link between the indicators at a conceptual level, an analytical exploration to demonstrate an empirical basis for these linkages in the South African context is presented. The *Pearson Product–Moment* correlation provides reliable estimations as to the degree to which a linear predictive relationship may exist between the various outputs of this research. A widely used guideline on the interpretation of correlation values is provided by Cohen: 0.1 for "small", 0.3 for "medium" and 0.5 for "large" correlation values (1988, 1992). The relationship between the indicators speaks to the reliability as well as acting as a proxy for culture of science within South Africa. The latent structures that drive such correlations remain essential artefacts of investigation toward mapping out the *cultural authority of science* in the developing world context.

A correlation matrix was developed for the 6 indicators at a national aggregate level to assess any relationships. Five of the indicators demonstrated slight positive correlations among each of them, while one indicator demonstrated negligible coefficient value to only a single indicator. While it is not expected that all indicators would demonstrate very strong relationships between them, it is expected that positive associations would be demonstrated among these theoretically related measures. The *science knowledge index* demonstrated slight positive relationships with the *Interest* (0.120**); *informedness* (0.122**); *info-source* (0.147*) and *engagement* (0.081*) indices. All of these correlations, while they may be considered small, are none-the-less positive and have been found to be statistically significant.

No significant association was demonstrated between the *knowledge index* and the *attitudinal index*, however, this has long been supported within the literature (Evans & Durant, 1995; Aminrad, *et* al, 2013). The *index of attitudes* to science was not correlated with any of the remaining five indices produced. A very small association with the *informedness index* was found to be statistically significant, however at the 0.045 value would in most cases be considered a negligible correlation outcome. This unique fingerprint of attitudes to science may be as a result of item selection or other unexplored factors and has been discussed in earlier research on the South African public understanding of science (Reddy *et al*, 2013).

		KNOWLEDGE INDEX	ATTITUDE INDEX	INTEREST INDEX	INFORMEDNESS INDEX	INFO SOURCE INDEX	ENGAGEMENT INDEX
KNOWLEDGE INDEX	Correlation	**1.00**	0.009	.120**	.122**	.147**	.081*
	Sig. (2-tailed)		0.631	0.000	0.000	0.000	0.014
	N	3188	3105	2512	3106	3021	906
ATTITUDE INDEX	Correlation	0.009	**1.00**	-0.030	.045*	0.000	-0.005
	Sig. (2-tailed)	0.631		0.128	0.011	0.991	0.868
	N	3105	3311	2584	3223	3127	936
INTEREST INDEX	Correlation	**.120****	-0.030	**1.00**	.537**	.352**	.172**
	Sig. (2-tailed)	**0.000**	0.128		0.000	0.000	0.000
	N	2512	2584	2640	2624	2531	875
INFORMEDNESS INDEX	Correlation	**.122****	**.045***	**.537****	**1.00**	.479**	.196**
	Sig. (2-tailed)	0.000	0.011	0.000		0.000	0.000
	N	3106	3223	2624	3346	3141	938
INFO SOURCE INDEX	Correlation	**.147****	0.000	**.352****	**.479****	**1.00**	.203**
	Sig. (2-tailed)	0.000	0.991	0.000	0.000		0.000
	N	3021	3127	2531	3141	3229	907
ENGAGEMENT INDEX	Correlation	**.081***	-0.005	**.172****	**.196****	**.203****	**1.00**
	Sig. (2-tailed)	0.014	0.868	0.000	0.000	0.000	
	N	906	936	875	938	907	950

** Correlation is significant at the 0.01 level (2-tailed)* Significant at the 0.05 level (2-tailed).

Table 2: *Correlation* between 6 indicators

With the exception of the *attitude index*, the *index of interest* in science was positively correlated with the *knowledge* (0.120**); *informedness* (0.537**); *info-source* (0.352*) and *engagement* (0.172*) indices. The association between scientific *interest* and scientific *informedness*, while theoretically expected, presented the highest correlation value among all indicators. A similar relationship, albeit smaller than the aforementioned, does exist between *interest* and the *information source* indicator, while between the *interest* and *engagement* indices, a small, though positive association exists. The relationships between *Interest*, *Information* seeking, *Informedness* and to a lesser degree *Engagement* is expected as these elements of the public understanding of science could be seen as nested within each other.

A statistically significant association was found between the *informedness index* and the *information immersion index* (0.479**) as well as the *science engagement index* (0.196**). The association between the *informedness index* and the *information immersion index*, demonstrates a similarly moderate positive association between these indicators. The *science engagement index*, in its relationships to the other indicators, was positively associated with the *information immersion index*

(0.203**). While many of these associations are below the level of 0.300, and may be considered *small*, the positive relationship between the variables is none the less an encouraging pattern within this exploratory investigation.

Following from the above discussion, a key conceptual question then follows, of how these patterns of correlation between the indicators may be shifting or remaining constant across the various strata within the South African population. An expectation would be that for the various strata, as influenced by location, income, employment, education and gender these patterns may shift. The next section investigates the stability of these patterns of correlation for the various strata within the South African population. Analysis was performed on the patterns of correlation across various demographic strata, including *geographic location, income, employment, education* and *gender* as factors of the different strata of the South African population. It is noted that many of these factors are not entirely independent from influence on each other, for the purposes of this analysis these factors were treated as *independent* to begin to isolate patterns of correlation across the indices[17].

Correlation analyses were completed for both the male and female sub-samples. Within the male sub-sample a statistically significant correlation was demonstrated between the *knowledge* index and the *interest* (0.103**)[18]; Informedness (0.110**); *information source* (0.128**) and *engagement* (0.107**) indices. The indices for interest; informedness; information source and engagement were all significantly correlated to each other. None of the indicators demonstrated a statistically significant correlation with the *attitudinal* index, among males. Within the female sub-sample the *knowledge* index demonstrated a statistically significant correlation with the *interest* (0.140**); Informedness (0.133**); *information source* (0.168**) and *engagement* (0.065**) indices. The indices for interest; informedness; information source and engagement were all similarly significantly correlated with each other.

In order to ascertain if the correlation scores between males and females were significantly different from each other the Fishers z-transformation was applied to the correlation scores. Outputs of this analysis indicates that across all indicators, male and female correlation values do not differ significantly from each other, except for the correlation between Information source and the engagement index (z-score: 2.650; P-value: 0.008), where males showed a statistically significant higher correlation between these indices.

[17] All demographic frequency data is presented in crosstab in appendix
[18] * indicates correlation is significant at the 0.01 level. ** indicates correlation is significant at the 0.05 level

South Africa has a number of highly developed urban centres; however it still has a large rural population relative to other countries. Within the urban sub-sample, statistically significant correlations were demonstrated between the knowledge; interest (0.114**); informedness (0.127**); information source (0.124**) and the engagement index (0.083**). Similarly, significant correlations were associated with interest and informedness (0.574**); information sources (0.388**) and the engagement index (0.263**). The indicators for informedness, information source and the science engagement displayed a similar pattern of correlation. As with the gender analysis, no significant association was found between the attitudinal index and any of the remaining 5 indicators. Within the rural sub-sample a comparable pattern emerged, with significant correlations between the knowledge indicator and the interest (0.129**); informedness (0.101**); information source (0.184**) and the engagement index (0.076**). A small positive correlation did exist between the attitude and informedness index (0.073*), however there were no statistically significant associations with any of the remaining indicators. The interest, informedness, information source and the science engagement indicator all showed strong patterns of positive associations with each other, as within the gender analysis.

Comparisons between the rural and urban sub-samples similarly indicate that the two populations mostly do not differ in terms of their correlation patters on these indices. Within the *interest index*, correlations with the *informedness index* (z-score: 3.986; P-value: 0.001); *information source* (z-score: 3.616; P-value: 0.003) and the *engagement index* (z-score: 2.486; P-value: 0.013) there was a statistically significant difference between these sub-samples. Similarly, the *engagement index*, the *informedness index* (z-score: 2.811; P-value: 0.005) and the *Information source index* (z-score: 2.188; P-value: 0.029) were found to be statistically different. This is however to be expected as a result of the limiting factors associated with cost, location and accessibility of information sources, engagement activities particularly within non-urban areas.

In South Africa, *matric* or grade 12 is the senior high school completion year. Individuals were classified as having *Pre-Matric* (39.3%); *Completed Matric* (45.3%) or *Post Matric* (15.5%) education. Within the pre-matric and matric completed sub-samples the profile of statistically significant correlations has not shifted dramatically. *Knowledge, interest, informedness, information sources* and *engagement* indices demonstrate statistically significant correlations among each other. No significant associations were demonstrated for the attitudinal index. Within the post-matric sub-sample, the pattern of correlation shifted slightly. The only indicator that was significantly associated with the knowledge index in this sub-sample was the informedness index (0.115**). Significant correlations continued to be demonstrated between the interest; informedness; information source and the engagement index.

Comparisons between the three sub-samples reveal that for the *pre-matric* and the *matric completed* groups, there were minimal differences in the z-scores and correlations on these indicators. Between these groups the correlation between the *interest* and the *engagement* indices did show a statistically significant difference, with the *matric-completed* group demonstrating a significantly higher correlation between these indicators than in the *pre-matric* group. Similarly, between the *post-matric* and *matric completed* groups only two indicators revealed a statistically significant difference, with the remainder showing little variation, across groups. These two indicators were *Interest – Informedness* (z-score: -3.066; P-value: 0.002) as well as *informedness – infosource* (z-score: -5.720; P-value: 0.000), which were both significantly different from the comparison groups. The pattern of correlation shifts dramatically when comparing the *pre-matric* and *post-matric* group. Within this comparison group, 7 of the 15 correlations were found to be significantly higher in the post-matric group than within the pre-matric group. This further emphasises the tremendous role of education within this context.

Employment remains a critical issue within South Africa. Among the sample in this study, 44.5% report being employed while 36.7% report being unemployed. A further 18.8% of respondents were not working, whom have either retired or are involved in unpaid activities. Among the employed and unemployed sub-samples the patterns of correlation coefficients do not change dramatically. However, within the unemployed sub-sample, the correlation between knowledge and engagement was not found to be statistically significant. Within both sub-samples no statistically significant association was demonstrated between the attitudinal index and the remaining 5 indicators. Within the *Other (Not Working)* sub-sample however, the *attitudinal index* did show a very small statistically significant negative correlation with the *interest index* (-0.093*). Within the same sub-group, the *knowledge index* was only significantly associated with the informedness index (0.140**) and the information source index (0.176**).

The patterns of correlation among the three employment categories did not shift dramatically between the sub-groups. There were no significant variations between the correlations of those *Employed* and respondents reporting *Other (Not Employed)*. In the comparison of those *Employed* and those *Unemployed*, the pattern remain relatively unchanged, with two exceptions. The correlation for *interest-informedness* (z-score: 2.885; P-value: 0.004), as well as *informedness-infosource* (z-score: 1.976; P-value: 0.048) were found to be statistically different between these groups. Similarly, for the sub-groups *Unemployed* and *Other (Not Employed)* the pattern remained similarly unchanged, with the exception of *Informedness-infosource* (z-score: 6.498; P-value: 0.000) and *Informedness-engagement* (z-score: -2.827; P-value: 0.005).

Related to employment, are issues of income as South Africa has a particularly high level of income inequality. The categories of household income considered include: *Low Income* (less than ZAR 10 000 per month); *Moderate Income* (Between ZAR 10 000 – ZAR 29 000 per month) and *High Income* (more than ZAR 30 000 per month). Across income category sub-samples a pattern of fewer statistically significant correlations between the indicators was observed. As income increases, so too did the count of correlating indices decrease. Within the low income group, knowledge was significantly correlated with interest (0.132**); informedness (0.122**) and information sources (0.142**). Similarly in this group the indicators for interest, information sources and engagement were similarly highly correlated. However, within the high income sub-sample, no indicators were significantly correlated with the *knowledge* or *attitude* indicators, nor were the *interest* and *engagement* indicators correlated. Significant correlations remained however between the *interest-informedness*; *interest-infosource*; *informedness-infosource* and *informedness-engagement* indices.

Fishers z-transformation was applied to the correlation scores for each the *Low, Moderate* and *High* income categories and the critical value for *p* was interpreted as an indication of any significant difference in the coefficients. Across all income categories there were very few significant differences demonstrated for the correlation values. *Interest-informedness* (z-score: -2.896; P-value: 0.004) and the infosource-engagement (z-score: 2.950; P-value: 0.004) comparisons showed a statistically significant difference in correlation scores. The differences among the *low-high income* correlations were similarly few. The *knowledge-interest* (z-score: 2.733; P-value: 0.006); *knowledge-infosource* (z-score: 3.060; P-value: 0.002) and the *interest-informedness* (z-score: -2.263; P-value: 0.024) correlations were all found to be statistically different between these groups.

Apparent within all of the observations on each index and within every stratum is that there appears to be areas of stronger correlation and areas of weaker correlation. Stronger correlations were demonstrated between the knowledge, interest, informedness, information source and engagement indicators. Juxtaposed to this, Attitude displayed weak correlations to most all of the comparisons with the previously mentioned 5 indicators. However as noted by Reddy *et al* (2013) as well as Guenther and Weingart (2016), South Africa does present a *unique profile* with regards to attitudes to science. This in particular requires further investigation to best understand the complex dynamics of South Africans attitudes to science.

While it is understood that this may be related to design factors such as the item wording and (or) data treatment approaches, across all these correlation analysis there appears to be a common latent structure underlying these observations. A factor analysis was conducted using the 6 indices in order to explore if there may be a latent variable that could explain the variance between the indicators. The results, based on eigenvalues greater than 1 indicate that there exist 2 factors that explain 51.2% of the total variance within these indicators. Factor 1 accounted for 34.5% of total variance while factor 2 accounted for 16.7% of the total variance encountered.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.068	34.469	34.469	2.068	34.469	34.469
2	1.001	16.685	51.155	1.001	16.685	51.155
3	.956	15.939	67.094			
4	.840	14.002	81.096			
5	.676	11.265	92.361			
6	.458	7.639	100.000			
Extraction Method: Principal Component Analysis.						

Table 3: Factor analysis 1: 6 indicators

Considering the results of the correlation analysis in this chapter, along with the correlation matrix produced within the factor analysis, it is apparent that the attitude index does not relate well to any of the related indices. This was removed from the procedure of a second factor analysis, producing the result in table 4 below.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.089	41.785	41.785	2.089	41.785	41.785
2	.951	19.023	60.808			
3	.839	16.774	77.582			
4	.666	13.320	90.903			
5	.455	9.097	100.000			
Extraction Method: Principal Component Analysis.						

Table 4: Factor analysis 2: 5 indicators (Attitude Index removed)

The result within the second factor analysis again demonstrates the existence of a latent structure accounting for a large share of the variance within the remaining indicators. The removal of the Attitude Index from the revised analysis similarly removed the second factor. The total variance explained by the factor identified is 41.8%. While it is clear that the patterns associated with the attitudinal index may require some additional work toward understanding the uniqueness of South African attitudes to science, this result none the less demonstrates a clear pattern of interrelatedness among the remaining 5 indicators. The above exploratory analysis may highlight a viable path toward mapping the structures and dimensions of the South African public understanding of science while simultaneously illuminating our understanding of the domestic cultural authority of science.

CONCLUSIONS: TOWARD MAPPING A SOUTH AFRICAN CULTURE OF SCIENCE

This chapter presents evidence for the vital and often misinterpreted role that the public has to contribute to the evolution of a national system of innovation. The historical account of science within various industrialised contexts have demonstrated that the public may direct and determine the trajectory of scientific institutions and science policy, through its understanding and engagement with the enterprise, even if this engagement is neither direct nor based on established evidence. Within a fledgling democracy, like South Africa, the history of science and the role it has played in shaping and determining current social realities of many of its citizen's remains an important consideration within a project that seeks to map the culture and authority of science.

The indicators produced within this study have helped to illuminate the understanding of the South African public understating of science along 6 dimensions. This has allowed insights into the positioning of science outside of established scientific structures, and views the domestic scientific contribution within the general public conversation. In many respects this offers the first snapshot of a *South African science culture* that is yet to be fully understood. This exploratory investigation then, represents a first attempt toward fully articulating the value of science and the role that it may play in South African social, economic and developmental landscape.

The South African public has in itself a significant level of variability with respect to the selected demographic criteria. Results from within the various indicators reveal that for each of the 6 dimensions, demographic classifications demonstrate a level of variability on index performance that is in many ways expected within a population like South Africa. The analysis presented unpacks the somewhat isolated set of indicators and attempts to understand the interconnectedness within the correlations between them. What is of particular relevance within the outcomes of this analysis is not necessarily the quantum of the outputs, but the patterns of correlation across the 6 indicators within this analysis for every socio-demographic classification.

Taking into account the diverse population and variations in demographic characteristics[19], performance on the various measures produced markedly differing results for each indicator within each population stratum. However when comparing the patterns of correlation among the 6 indicators, within each stratum, it emerges that there is very little variation within these patterns across demographic strata. There remains a clear pattern of connectedness across the indicators at both the national aggregate level and similarly so within each of the demographically based stratum. What is clear is that the *attitudinal* measures and similarly the *knowledge* measures present low patterns of correlation across every stratum. However, the indicators for *interest*, *informedness*, *information* sources and *science engagement* exhibit a high degree of correlation and may present a viable starting point toward mapping the culture of science in South Africa. While the observations and analysis did demonstrate some shifting patterns of correlation, the related z-scores demonstrate that much of this pattern movement was not a significant shift. This may indicate that despite the discussed social and cultural multidimensionality in South African society, matrices such as these may present a proxy for understanding the authority of science within this population. Exploratory factor analysis similarly disclosed the existence a underlying latent structure that appears to explain a high degree of the variance across 5 of the 6 indicators within this dataset.

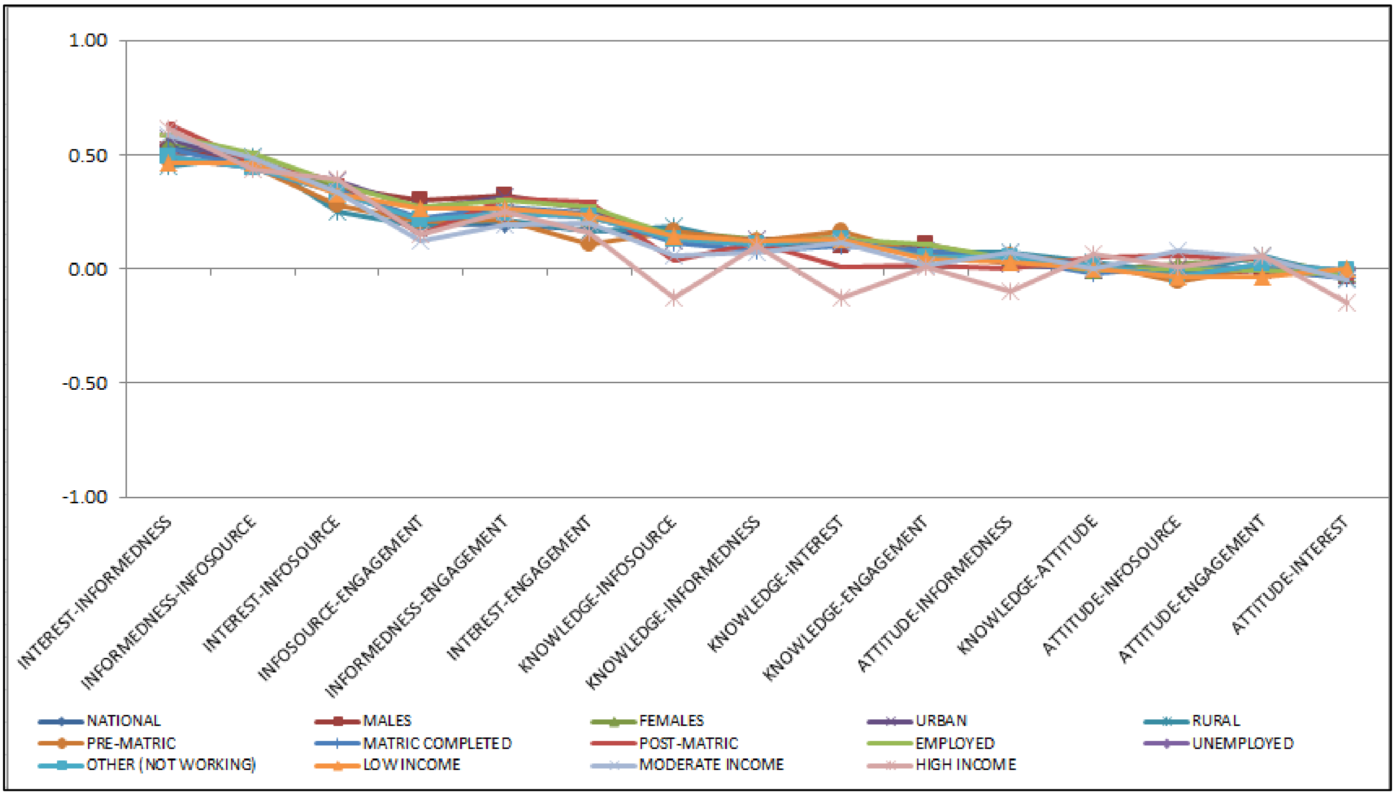


Chart 1: *Correlation* between 6 indicators for all sub-stratum of SA population

[19] See appendix tables for these demographic variations in cross tabs

As a developing nation, emerging from a dark history and wrestling with the social, cultural and political legacy impacts of racially separated development, South African stands facing a daunting developmental challenge. However, similarly so this point in history presents a tremendous opportunity to leverage the current canvas toward fostering a stronger culture of science within the population. The success experienced within the Indian population provides a key example of how developing economies can leverage success despite the challenge of inequality, poverty and lack of infrastructure. The Indian space programme and particularly the *Mars Orbiter Mission* is just one such example of this success. The Indian Space Research Organisation (ISRO) was able to launch a transmitting vehicle from Earth into a Mars orbit, at a lower cost than Hollywood could produce a fictional movie about a manned mission to Mars[20]. Much of the success within the Indian example could be attributed to the concept of a *scientific temper* coined by Prime Minister Jawaharlal Nehru in the mid 1940's and has urged the Indian population to adopt a scientific approach to problem solving. Such a science culture has demonstrated tremendous success and while even on the sub-continent, work is continually evolving, and the lessons are applicable equally in the West as it is in the East.

Within South Africa, as elsewhere, the culture of science could be considered by proxy within a structural set of patterns between variables (Bauer & Suerdem, 2016). The assessed similarity and minimal difference across the correlations between the indicators at varying strata of the South African population, despite the known diversity within the people, represents an interesting departure for advancing such analyses as proxy representations of the domestic *cultural authority of science*. While the nature of this analysis is exploratory, and has a number of limitations within its design and methodological approach it may highlight clearer direction within the South African context toward understanding science culture within the diverse South African publicS.

[20] The *Mangalyaan* mission cost ISRO $73 Million USD; *The Martian* had a production budget of $108 Million USD.

		GENDER		LOCATION		EMPLOYMENT			INCOME			EDUCATION		
		Female	Male	URBAN	RURAL	EMPLOYED	UNEMPLOYED	OTHER (NOT WORKING)	LOW INCOME	MODERATE INCOME	HIGH INCOME	PRE-MATRIC	MATRIC COMPLETED	POST-MATRIC
GENDER	Female	1747		1153	594	628	731	388	820	244	69	728	786	233
	Male		1739	1144	595	925	548	266	809	253	76	641	792	306
EDUCATION	PRE-MATRIC	728	641	737	632	383	675	311	779	65	3	1369		
	MATRIC COMPLETED	786	792	1111	467	755	557	266	747	274	46		1578	
	POST-MATRIC	233	306	449	90	415	47	77	103	158	96			539
EMPLOYMENT	EMPLOYED	628	925	1158	395	1553			676	337	121	383	755	415
	UNEMPLOYED	731	548	721	558		1279		696	79	10	675	557	47
	OTHER (NOT WORKING)	388	266	418	236			654	257	81	14	311	266	77
INCOME	LOW INCOME	820	809	988	641	676	696	257	1629			779	747	103
	MODERATE INCOME	244	253	402	95	337	79	81		497		65	274	158
	HIGH INCOME	69	76	134	11	121	10	14			145	3	46	96
LOCATION	URBAN	1153	1144	2297		1158	721	418	988	402	134	737	1111	449
	RURAL	594	595		1189	395	558	236	641	95	11	632	467	90

Appendix : Demographic characteristics of sample.

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