Factors influencing the public communication behaviour of publicly visible scientists in South Africa

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Declaration

By submitting this dissertation electronically, I declare that the entirety of the work contained therein is my own original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously submitted it, in its entirety or in part, for obtaining any qualification.

Ethical clearance for this study was obtained from the Research Ethics Committee: Human Research (Humanities) at Stellenbosch University, during November 2016, reference number: SU-HSD-004069.

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Abstract

Given the policy intention of the South African government to encourage and support public science engagement, this study set out to identify and understand the factors that influence scientists' behaviours as far as public communication about their work is concerned.

Based on an extensive literature review and interviews with 30 publicly visible scientists, a complex blend of factors that influence scientists' participation in public science communication were identified and explored. Important factors included field of research, career stage, age, gender, personality and population group, as well as scientists' attitudes towards communication platforms and the public. Furthermore, this study yielded new insight into the influence of the historical, bio-geographical, cultural and socio-political contexts on scientists' engagement with public audiences, while also highlighting how their communication behaviour is shaped by institutional environments and national contexts. The population group to which the individual scientists belong emerged as an important factor in terms of scientists' perceived ability to connect with multi-cultural and multi-lingual audiences in South Africa.

In light of changes in the norms that govern scientists' behaviour, and contradictory policies that scientists may encounter, the conflicted and contested nature of public science communication was highlighted, along with scientists' resulting ambivalence about their own participation in these activities.

The current study shows that visible scientists in South Africa are mostly keen to engage with public audiences, and that they are typically motivated towards public engagement by a blend of intrinsic and extrinsic rewards. Time constraints and a lack of institutional support, incentives and recognition remain key barriers which limit scientists' participation in public communication of science. Earlier findings that visible scientists are typically highly productive leaders in the science community were validated, thereby challenging the perception that public science communication carries a stigma and is too time-intensive to accommodate in the career of a serious scientist.

Based on the findings in this study, it is recommended that policymakers who seek to stimulate quality and/or quantity of public science engagement, need to focus on the contextual factors, i.e. the policies and support structures in the institutions where scientists work. Further policy implications that are outlined include the value of mobilising black scientists as role models and enabling visible scientists to act as communication mentors, as well as the need to ensure responsible use of social media and ethical science PR practices in public communication of science.

Keywords: Science communication; public science engagement; visible scientists; science and media; science and social media; science PR

Opsomming[1]

Gegewe die beleidsrigting van die Suid-Afrikaanse regering om skakeling tussen wetenskap en die publiek aan te moedig en te ondersteun, was dit die oogmerk van hierdie studie om die faktore wat die openbare kommunikasie van wetenskaplikes bepaal, te identifiseer en te verstaan.

Op grond van ʼn omvattende literatuuroorsig en onderhoude met 30 wetenskaplikes wat in die openbaar sigbaar is, het ʼn veelkantige beeld van die ingewikkelde vermenging van faktore wat wetenskaplikes se deelname aan openbare wetenskapskommunikasiegedrag beïnvloed, na vore gekom. Studieveld, loopbaanstadium, ouderdom, geslag, en persoonlikheidstipe is belangrike faktore, asook wetenskaplikes se houding aangaande kommunikasiekanale en die publiek. Hierdie studie het voorts insae gelewer aangaande die invloed van historiese, sosio-politieke, morele, kulturele en bio-geografiese konteks, sowel as die institusionele omgewing waar wetenskaplikes werk. Die bevolkingsgroep waaraan die wetenskaplikes behoort, is geïdentifiseer as ʼn beduidende faktor wat hulle waargenome vermoë om met multikulturele en veeltalige gehore in Suid-Afrika te werk, bepaal.

In die lig van veranderinge in die norme wat wetenskaplikes se openbare kommunikasiegedrag bepaal, sowel as opponerende beleidsrigtings waarmee navorsers te make kry, is die konflikterende aard van openbare wetenskapskakeling uitgewys, sowel as hoe dit lei tot wetenskaplikes se ambivalensie oor hulle eie betrokkenheid by hierdie aktiwiteite.

Die huidige studie toon dat sigbare wetenskaplikes in Suid-Afrika oor die algemeen gretig is om met openbare gehore te skakel, en dat hulle deur ʼn mengsel van interne en eksterne belonings gemotiveer word. Tydsbeperkings en ʼn gebrek aan institusionele ondersteuning, aansporings en erkenning het na vore gekom as die vernaamste struikelblokke wat navorsers se deelname aan wetenskapkommunikasie beperk. Vorige bevindinge dat sigbare wetenskaplikes ook produktiewe leiers in die wetenskapgemeenskap is, is bevestig. Sodoende is die idee dat daar ʼn stigma kleef aan openbare wetenskapkommunikasie en dat hierdie aktiwiteite te tydrowend is vir ernstige wetenskaplikes, uitgedaag.

Op grond van die bevindings wat hierdie studie opgelewer het, word aanbeveel dat beleidvormers wat daarna streef om die gehalte en/of hoeveelheid openbare wetenskapskakeling aan te moedig, aandag moet gee aan die konteksgebonde faktore, d.w.s. die beleidsriglyne en ondersteuningstrukture van die instellings waar wetenskaplikes werk. Ander moontlike beleidsimplikasies wat uit die huidige studie na vore gekom het, sluit in die waarde daarvan om swart wetenskaplikes as rolmodelle te mobiliseer, asook om sigbare wetenskaplikes in staat te stel om as mentors vir wetenskapkommunikasie op te tree. Verder is klem gelê op die belangrikheid van verantwoordelike gebruik van sosiale media en etiese praktyke in openbare wetenskapskakeling.

Sleutelwoorde: Kommunikasie van wetenskap; openbare betrokkenheid by wetenskap; sigbare wetenskaplikes; wetenskaplikes en die media; wetenskaplikes en sosiale media; openbare wetenskapskakeling.

[1] Abstract in Afrikaans.

Acknowledgements

The road towards a PhD can be long and arduous. And, if you tackle this journey later in life, as I did, there is considerable pressure to keep up the pace and get to the finish line in good time. Inevitably, there were moments of doubt along the way. But there were also moments of pure delight, such as the joy of discovering what iconic scientists said about sharing science with the public 100 or more years ago, the thrill of finding a new study that provided valuable perspectives, and the pleasure of spending time with some of the leading scientists in South Africa.

When at times, the road seemed long and lonely, I drew inspiration from a story that Professor Bruce Rubidge shared with me about the painstakingly slow work required to free a fossil from a rock. When he became impatient one day, and broke a chisel in the process, his technical assistant looked at him and said: *"Bietjie bietjie maak baie"* (English: A little bit at a time eventually adds up to a lot.) So, Bruce told me: If you do things bit by bit and keep going, you will eventually achieve your goal. Along the way, I was fortunate to be surrounded by family, friends and colleagues who never doubted that I would be up to the task. I'm particularly grateful to the following people:

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Photographs: The photos of the visible scientists I interviewed were taken by me or supplied by them.

To my father, Pieter du Toit.

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List of acronyms and abbreviations

AAAS	American Association for the Advancement of Science
AEL	Academy of Environmental Leadership
Aids	acquired immunodeficiency syndrome
ARC	Agricultural Research Council
BBSRC	Biotechnology and Biological Sciences Research Council
BSE	bovine spongiform encephalopathy, commonly known as 'mad cow disease'
CAPRISA	Centre for the Aids Programme of Research in South Africa
CEO	chief executive officer
CNRS	*Centre national de la recherche scientifique*
CPUT	Cape Peninsula University of Technology
CREST	Centre for Research on Evaluation, Science and Technology
DST	Department of Science and Technology
EPA	Environmental Protection Agency
EU	European Union
EWN	Eyewitness News
GMO	genetically modified organism
HIV	human immunodeficiency virus
HSRC	Human Sciences Research Council
JCOM	Journal of Science Communication
MIT	Massachusetts Institute of Technology
MMR	measles, mumps and rubella
MOOC	massive open online course
MRC	Medical Research Council
NHLS	National Health Laboratory Service
NIH	National Institutes of Health
NICD	National Institute for Communicable Diseases
NRF	National Research Foundation
NSF	National Science Foundation
NSTF	National Science and Technology Forum
PCST	public communication of science and technology
PR	public relations
RRI	responsible research and innovation
SAASTA	South African Agency for Science and Technology Advancement
SKA	Square Kilometre Array
STEM	science, technology, engineering and mathematics
SU	Stellenbosch University
TB	tuberculosis
UCT	University of Cape Town
UFS	University of the Free State
UK	United Kingdom
UKZN	University of KwaZulu-Natal
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UP	University of Pretoria
US	United States
Wits	University of the Witwatersrand
WWI	First World War
WWII	Second World War
CSIR	Council for Scientific and Industrial Research
DACST	Department of Arts, Culture, Science and Technology
DFID	Department for International Development
GM	Genetically modified
NCCPE	National Coordinating Centre for Public Engagement
www	World Wide Web

Chapter 1: Research question, study structure, rationale and definitions

The science popularisers are ambassadors, messengers from the scientific community to the public at large.
(Giberson, 2011:217)

1.1. Research question

This study – the first of its kind in South Africa – explored the factors that motivate scientists to engage with public audiences, and consequently become visible in the public arena. It explored similarities and differences between the factors that motivate local scientists towards public communication, with factors that have been shown to influence the communication behaviour of scientists in other parts of the world.

Despite some critical voices that question the motives behind public communication of science (e.g. Weingart, 2012; Marcinkowski & Kohring, 2014; Weingart & Guenther, 2016), effective engagement between scientists and diverse publics is increasingly recognised as an important characteristic of a modern, democratic knowledge society (Horst, 2013; Trench *et al*., 2014; Lewenstein, 2016). Likewise, the notion that scientists should emerge from the proverbial ivory tower to discuss issues rooted in science and engage with affected publics, has become a central element of the moral economy of modern science (Davies, 2008; Cronin, 2010; Foley, 2016). As a result, the public communication of science has attracted considerable attention since the late 20th century, especially in the higher education sector (Neresini & Bucchi, 2011).

In the light of escalating policy and funding directives aimed at facilitating engagement between scientists and public audiences, it is vital to understand which factors either motivate or deter scientists when it comes to participating in public communication activities (Markowitz, 2017).

In order to study the factors that influence scientists' communication behaviour, it makes sense to focus on scientists with experience of engaging public audiences. This study therefore focused on scientists who have achieved some level of public visibility, since I expected that, based on their experience of one or more forms of public engagement, they would be able to reflect on the factors that have encouraged or constrained their own involvement in public science communication (Goodell, 1975).

Given the contested nature of public communication of science (Weingart & Guenther, 2016), most scientists are likely to experience contradictory demands in terms of their public profile. On the one hand, normative influences, rooted in sociological reasons as spelled out by Merton (1973), may curb scientists' willingness to become more visible in the public arena. On the other hand, the demand for scientists to engage is justified politically (publicly funded researchers owe a debt to the taxpayer) as well as democratically (in a democratic society, citizens have access to the latest information). Furthermore, intense competition between scientific institutions has resulted in the use of science communication to compete for public attention and support, and the science communication arena becomes even more conflicted as public communication of science is used to promote the image and profile of institutions and individual scientists. This study therefore also explored this public–science conundrum, which results from competing and often opposing influences that shape scientists' public communication behaviour.

Therefore, the overarching research question guiding this study was: **Which factors influence the communication behaviour of publicly visible researchers in South Africa?** In other words, the focus of this study was on the scientists themselves. Guided by this question, this study sought to identify and explore the factors that have an influence on the public science communication behaviour of researchers who are actively participating in public science communication. It explored the motivations and objectives that drive scientists to communicate with external audiences, but also the barriers that stand in their way.

The study comprised the following three phases:

- Phase one lay the groundwork with a comprehensive review of research literature dealing with the factors that influence researchers' public science communication behaviour.
- In the next phase, publicly visible scientists currently living and working in South Africa were identified with the help of a panel of science-media experts.
- The final phase comprised interviews with 30 publicly visible scientists in South Africa, and the interpretation of the interview data within the socio-political context of South Africa.

1.2. Study overview and structure

This dissertation is structured as follows:

- In Chapter 1, I pose the research question and the rationale, and define the key concepts that were relevant to this study.
- As a departure point for the literature review and empirical work, I propose a conceptual framework, informed by a spectrum of theoretical considerations regarding human behaviour, in Chapter 2.
- In the literature review, presented in Chapter 3, I discuss existing evidence on how the factors included in my conceptual framework have been shown to influence public science communication.
- For the empirical component of this study, I conducted in-depth, qualitative interviews with 30 scientists who were identified as visible in the public sphere with the help of a panel of science-media experts. My research design and methods are outlined in Chapter 4.
- The results of the current study, including my interview data, are presented and discussed in Chapter 5.
- Reflections on key findings and some recommendations are contained in Chapter 6, along with the study limitations and suggestions for future research.
- The final sections of the dissertation consist of a list of literature references and relevant appendices.

1.3. Study rationale

Below, I expand on the rationale for the current study, based on the need to focus on the role of scientists in public science engagement, the motivation for doing the study in the South African context, as well as the reasons for focusing on publicly visible scientists.

1.3.1. The focus on the scientist's perspective

Psychologists Webb and Poliakoff (2008) make a strong case for using insights from research in the field of psychology to understand why scientists do or do not participate in public engagement, and to design appropriate interventions that will encourage their involvement.

Since the 1960s, numerous studies have focused on public attitudes to science (e.g. Miller, 1983; 1998; 2004; Bauer, Allum & Miller, 2007; Bauer & Howard, 2013), but research about scientists' attitudes and behaviours in terms of public communication is much less common. Several scholars highlight the scarcity of studies exploring the role of scientists in public engagement (Bodmer & Wilkins, 1992; MORI, 2001; Felt, 2003; Losh, 2010; Searle, 2011; Dudo, 2015), and emphasise the need to understand fully the influences, motivations and perceived barriers that affect scientists' public communication behaviour in order to support meaningful and sustained interaction between scientists and their publics (Mathews, Kalfoglou & Hudson, 2005; Poliakoff & Webb, 2007; Corley, Kim & Scheufele, 2011; Johnson, Ecklund & Lincoln, 2014; Besley, 2015a). For example, Grand, Davies, Holliman and Adams (2015) demonstrate the importance of evidence of how researchers conceptualise and view public engagement and select audiences for engagement work. In her motivation for the importance of understanding the aims, motivations and behaviours of individual scientists when it comes to public communication, Davies (2008:414) writes:

> In practice, it is individuals or small groups of technical experts who come into contact with publics, not science as an institution or an establishment. And it is therefore the practices of individuals which will frame and shape the communication process.

A further motivation for focusing on the views and attitudes of scientists themselves is the recognition that "the scientific community is necessarily the ultimate source of scientific understanding" (Bodmer, 1985:24).

Science communication scholars[2] who have taken the lead in exploring the communication attitudes and motivations of individual scientists include Rae Goodell, Sharon Dunwoody, Anthony Dudo, John Besley, Dominique Brossard, Hans Peter Peters, Sarah Davies, Massimiano Bucchi, Simone Rödder and Luisa Massarani. However, the bulk of science communication research continues to neglect the views of scientists themselves (Crettaz Von Roten, 2011) and do not sufficiently explore the difficulties that scientists experience when it comes to public science communication (Mizumachi, Matsuda & Kano, 2011).

[2] Examples of relevant studies include Goodell (1975), Dunwoody (1986), Dunwoody et al. (2009), Besley, Oh and Nisbet (2012), Bucchi and Saracino (2012), Rödder (2012), Davies (2013b), Peters (2014), Besley (2015b) , Koh, Dunwoody, Brossard and Allgaier (2016), and Massarani and Peters (2016).

Consequently, we remain uncertain about how scientists are responding to new demands for increased public engagement (Peters, Dunwoody, Allgaier, Lo & Brossard, 2014). Dudo (2013:478) articulates the need for further research in this field as follows:

> […] there is still much to learn about the crux of the PCST[3] issue: the factors and processes that lead scientists to interface with non-scientists. This lack of knowledge is due, in part, to a relative paucity of research. Only a handful of empirical studies have attempted to identify factors salient to scientists' PCST perceptions and behaviours.

Furthermore, most of the studies exploring the communication behaviour of scientists are quantitative in nature, which is useful to explain frequencies and modes of interaction between scientists and external audiences, but lacks explanatory value in terms of a deeper understanding of how scientists themselves perceive and respond to the benefits and rewards of public science engagement, as well as the obstacles that limit their participation (Webb & Poliakoff, 2008). Van der Auweraert (2008) notes the complexity of trying to change researchers' attitudes towards public communication, noting that it will require far more than simply identifying and removing external barriers. Instead, the author argues, it is necessary to study scientists' personal characteristics, attitudes towards their profession and their views of the science–society relationship, in order to understand, and possibly adjust, their behaviour.

1.3.2. The need to do the study in South Africa

The rationale for doing this study in South Africa[4] was based on the fact that similar studies were done almost exclusively in the developed world,[5] with inadequate attention paid to researchers in Africa and other parts of the developing world. Since the relationships between scientists, communication channels and publics are influenced by culture, politics and socio-economic conditions (Leshner, 2003; Mathews *et al.*, 2005; Kreimer, Levin & Jensen, 2011; Trench *et al.*, 2014), these relationships may vary across different regions of the world. Accordingly, comparative cross-country studies show that trends observed in one part of the world do not always apply elsewhere and that it could be misleading to expect that approaches to public science communication could be transferred successfully between countries (Trench *et al.*, 2014). Therefore, while insights gained from global research are valuable, it is not sufficient to rely on studies done elsewhere to understand the factors that influence the science communication behaviours of South African researchers. Moreover, public science communication in South Africa faces particular challenges and barriers related to cultural and language diversity, illiteracy, poverty and remote rural populations (Manzini, 2003; Joubert, 2007; Du Plessis, 2008)

This study was therefore designed to distil relevant insights from global research literature, and to apply these to qualitative empirical work in South Africa, in order to fill gaps in our knowledge and

[3] PCST is a commonly used abbreviation for 'public communication of science and technology'.

[4] South Africa offers a unique socio-political setting for this study (see 1.4).

[5] See Appendix 1 for a list of 107 relevant studies published between 1991 and 2016.

understanding of the factors that motivate or deter local scientists in terms of public science communication.

While the South African government has committed itself to the promotion of public science engagement, science communication research (that can inform best practice in the field) is in its infancy in the country and on the continent. A study by Guenther and Joubert (2017) shows that science communication research from Africa contributed only 1.1% of the total research output in three main journals in the field between 1979 and 2016, while authors based at African institutions contributed only 0.007% of the total authorship over the same period.

1.3.3. Reasons for focusing on publicly visible scientists

In a world where scientists are increasingly aware of the power of public science communication, time and effort are invested in external communication, and scientists take active control over their public appearances. This trend intensifies in the fast-changing, new media landscape of the 21st century where visibility is becoming an ever more important tool to gain attention and recognition (Fahy & Nisbet, 2011; Nisbet & Markowitz, 2015a).

However, scientists' active participation in public science communication (for example, presenting popular talks at schools and science centres) is not sufficient to ensure a high public profile. Public visibility requires an amplification of the individual scientist's views and voice, which can only be achieved via the media (Goodell, 1977) and including active involvement in public debates (Peters, 2014). Consequently, visible scientists have first-hand experience of the challenges, demands, risks and rewards of public communication, as well as the support and responses (or a lack thereof) from their peers, colleagues and institutions.

Goodell (1977) notes that visible scientists are unusual. Such scientists are able to deal with conflicting demands, including pressures from the science community to concentrate on science, pressures from society to give a public perspective on their work, and pressures from the media to conform to news values. Not only do these scientists have the skills to use communication channels effectively; they also invest time and effort to do so. At times, they may be praised by their institutions for raising the profile of their work, but they also risk criticism and disdain when controversies erupt in the public sphere. Visible scientists are further likely to be in fairly senior positions, as it takes time to achieve public visibility. Scientists who have achieved a high public profile would therefore be able to reflect on organisational policies and incentives that shape public communication. Goodell concludes that visible scientists "deserve a closer look" (Goodell, 1977:9). Based on their public visibility, these scientists may be considered as individuals who are ideally placed to consider the influences that encourage or restrict scientists' involvement in public science communication. A deeper understanding of these factors, particularly in the South African context, could clarify the best way forward in terms of increasing the scope, frequency and quality of public science engagement in South Africa. This is a major policy objective of the South African government (Department of Science and Technology [DST], 2014).

In the current study, publicly visible scientists were defined as scientists who are deemed to be 'visible in the public eye' by a panel of science-media experts, similar to the approach used in a landmark study of visible scientists conducted by Goodell (1975).

1.4. The unique South African context for this study

South Africa does not have a long track record of making science publicly accessible or engaging the broad society in dialogue about science. Under the rule of the apartheid government (1948–1994), scientific expertise was a strategically important political tool, purposely isolated from large tracts of society, while public investment in science was primarily geared towards advancing the objectives of the government at the time (Pandor, 2012). However, despite the "turbulence of apartheid" (Sooryamoorthy, 2010:379) that brought about international isolation, boycotts, sanctions and travel restrictions, the South African science base continued to strengthen during the apartheid era and the country developed advanced facilities and expertise in fields such as geology, mining, energy, nuclear science, space science, agriculture and veterinary science. However, much of this research was secretive and ignored the needs and knowledge system of the majority of the country's population, who remained disconnected from the science agenda of apartheid South Africa (Du Plessis, 2008).

The arrival of democracy in 1994 changed South African society profoundly. In this new dispensation, science and technology are seen as essential instruments for economic growth and social development. Democracy brought with it an expectation that science should also be democratised. One of the first science policy instruments of the new government was the 1996 White Paper on Science and Technology (Department of Arts, Culture, Science and Technology [DACST], 1996:76). This document articulated the need to place science and technology in the public domain as follows:

> For the national system of innovation to become effective and successful, all South Africans should participate. This requires a society which understands and values science, engineering and technology and their critical role in ensuring national prosperity and a sustainable environment. This, in turn, requires that science and technology information be disseminated as widely as possible in ways that are understood and appreciated by the general public.

This white paper called on publicly funded researchers to articulate the benefits of their work clearly to decision-makers and the public. It emphasised the need to make information about science and technology available to rural populations (to women in particular) in order to empower them to participate more fully in the transformation process in South Africa. It called for campaigns to promote science literacy, awareness and appreciation. The white paper resulted in 'The Year of Science and Technology 1998', which was a year-long, nation-wide, government-funded science communication campaign (Joubert, 1998).

The 2002 National Research and Development Strategy (DST, 2002) called for extensive investment in science promotion, and particularly the use of the mass media to make science attractive, accessible and relevant to the South African public. In the same year, the Department of Science and Technology (DST) established the South African Agency for Science and Technology Advancement (SAASTA) as a business unit of the National Research Foundation (NRF) with the mandate to advance public science awareness, appreciation and engagement in the country. These developments in South Africa echoed similar government policies and programmes in other developing countries, such as China (Jia & Liu, 2014), Brazil (Massarani & De Castro Moreira, 2016) and India (Rautela & Chowdhury, 2016).

Since the early 1990s, a handful of South African researchers started looking at scientific literacy, public understanding of science and public attitudes to science (e.g., Pouris, 1991, 1993, 2003; Blankley & Arnold, 2001). Low levels of interest in and understanding of science among South African adults were generally attributed to the legacy of education boycotts during the apartheid era. A more recent overview of public attitudes to science reveal a "complex and shifting balance between attitudes of promise and reservation" (Reddy, Gastrow, Juan & Roberts, 2013:6).

The DST ten-year plan for 2008–2018 (DST, 2007:23) once again accentuates the need to support public engagement with science and to include the public in debates and decision-making around science:

> As South Africa strives to become an innovative society, it is essential to support the public understanding of and engagement with science. Government's starting point is that the members of 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.

In 2014, the DST announced a new strategic framework for public science engagement (DST, 2014:3) intended to coordinate and encourage science promotion, communication and engagement activities at national level. In this policy directive, the DST emphasises the importance of so-called 'key enablers' to achieve its goals, including effective coordination, an enabling regulatory framework, adequate funding and a science engagement information system. The implementation of this DST engagement strategy features prominently in the 2015 NRF strategic plan (NRF, 2015).

As shown here, the South African government has repeatedly demonstrated its commitment towards public science engagement through a number of institutional and policy directives and instruments. Within this context, a better understanding of how South African scientists perceive and experience public science communication, and the factors that motivate or deter their involvement, could be useful in the management and evaluation of programmes and structures designed to support scientists' participation in public engagement activities.

It is hoped that this study will yield evidence that could meaningfully inform policies at governmental and institutional level to encourage and support sustained and responsible public communication of science.

1.5. Personal interest in the topic

Dudo and Besley (2016) propose that communicating with the public comes naturally for some scientists (noting Neil deGrasse Tyson, Carl Sagan and Stephen Jay Gould as examples) while others do not invest much thought or effort in outward-facing communication. This was also my experience during the course of my early career at the NRF, and in subsequent years when I worked as a science communication consultant for various organisations, including a ten-year contract with the Square Kilometre Array (SKA) project in South Africa. I was intrigued by the variability in scientists' responses towards opportunities to communicate with the public. I found that some scientists (they were the exceptions) responded enthusiastically and readily embraced new communication platforms, and pro-actively solicited media attention for their research. The bulk of the researchers who crossed my path were more reserved in their approach to public science engagement. They were unlikely to initiate public communication activities and were cautious about speaking to the media. These scientists would typically agree to an interview or a public talk, provided someone else took care of the arrangements and provided them with a platform, and some help in preparing for the activity. Also, when these scientists agreed to be interviewed, they would often introduce their own risk-reducing conditions, typically by insisting on reviewing a copy of the article before it went to print. I also worked with researchers who were of the opinion that public science communication was an optional undertaking. They could, at best, be persuaded to participate in public communication at the end of a research project, and only once their findings had been published in a peer-reviewed journal. A small group of scientists could not be persuaded of any benefit in engaging with the public. These researchers were frequently hostile towards journalists, and viewed media visibility as potentially perilous and detrimental to their scientific careers.

I experienced that not only scientists, but also the universities that employed them, had divergent attitudes and policies regarding public science engagement. Some universities pro-actively invested in encouraging and supporting their research staff members (and their achievements) to become publicly visible, while others largely ignored scientists and their work in terms of their public communication efforts. It is entirely possible that a desire to build institutional reputation, rather than a desire for dialogue with society, motivate the pro-communication universities, as has been suggested by Weingart and Guenther (2016). In addition to institutional differences in terms of public science communication policy and support, I observed large differences in the attitudes of researchers within a single institution, with some noticeably more willing and interested to engage external audiences than colleagues at the same university. Therefore, while it is evident that organisational culture shapes the communication behaviours of staff members, researchers are also influenced by factors not directly related to the institutional environment.

Based on these observations, I became particularly interested to explore and understand the factors that motivate or deter South African researchers in terms of their communication with public audiences. This was the focus of this study.

1.6. Science communication: definitions and concepts

Science communication is in fact a multifaceted phenomenon: it employs a variety of formats and channels of communication, involves different actors, and pursues very different, even sometimes conflicting, objectives.
(Marcinkowski & Kohring, 2014:1)

Since the public communication behaviour of scientists was the key focus of the current study, it was essential to conceptualise and define 'public science communication' comprehensively, as well as to distinguish it from scholarly communication. Scholarly (or professional) communication takes place inside science, and is mainly aimed at peers. Public communication takes place outside the science arena, and is mainly aimed at non-experts. Gregory (2015:220) highlights interesting differences in the rhetorical conventions that characterise these two types of communication, which explains some of the inherent tensions between these two modes of communication:

> Where scientists tend to express their professional claims in tentative, conservative, and incremental terms, science communication deploys a rhetoric of achievement and change, often with confident portrayals of the future. Science communication has traditionally privileged the visual, deploying the evidence of the senses, in the same way as professional science privileges the mathematical, calling on the capacities of intellect and education. Science communication uses literary devices such as narrative, metaphor, and anthropomorphism in contrast to the largely forensic language of professional communication.

Weingart (2017b) distinguishes between communication 'in, of and about' science, pointing out how the role players, functions and challenges differ. I provide a synopsis in Table 1.1.

Table 1.1: Representation of communication in, of and about science

Communica-tion	Communicated by	Media	Publics	Functions	Challenges
In science	Specialists within field	Science journals (disciplinary)	Scientific community (disciplinary)	Knowledge production	Access, both material and intellectual
	Specialists between fields	Science journals (interdisciplinary)	Scientific community (interdisciplinary)	Knowledge production; problem-solving	Access, both material and intellectual, politicisation
Of science	Specialists, science organisations, universities, associations, ministries, science journalists	Popular books, journals, radio, TV, museums, science cafés, etc.	Specific: youth Unspecific: general	Education, enlightenment, raising interest, acceptance, public relations	Demarcation, factual and persuasive communication, trust
About science	Science journalists, bloggers, laymen	Newspapers, blogs, social media, exhibitions	General public	Participate, comment, criticise, democratic control	Loss of professional mediator, competence, gain in reach
	Authors of novels, stories, historians	Novels, short stories, films, cartoons	General public, children	Entertainment, edutainment, critique	Relationship fact–fiction, stereotypes

(Source: Weingart, 2017b)

In a somewhat similar vein to the representation above, Marcinkowski and Kohring (2014) suggest the following distinction between three types of science communication.

- Communication by **individual** scientists versus **institutional** communication done by professional communicators.
- Communication **by** science (self-descriptions by academics and research organisations) versus communication **about** science (where external observers, mostly journalists, are doing the communication and placing the findings in a social context).
- Different modes of communication as defined by the relationships between communicators and recipients. In the case of so-called 'push communication', the communicator purposefully targets desired audiences by, for example, mailing materials or issuing press releases. 'Pull communication' involves making information available via dispersed channels so that recipients can find it according to their interests and needs. Blogs and journal articles are examples of 'pull communication'.

Many scholars have commented on the diversity of public science communication and its myriad forms and functions that surface via a multitude of platforms and channels. As noted by Burns, O'Connor and Stocklmayer (2003:183), "the meaning of science communication and other terms used in the field of scientific literacy has been plagued by an unfortunate lack of clarity". Consequently, many different terms,[6] often with overlapping meanings, are used to describe these activities. Examples are 'public understanding of science' (Pearson, Pringle & Thomas, 1997); 'knowledge transfer' (Jacobson, Butterill & Goering, 2004); 'public engagement' (Bauer & Jensen, 2011; Grand *et al.*, 2015) and 'science dissemination' (Torres-Albero, Fernandez-Esquinas, Rey-Rocha & Martín-Sempere, 2011).

Public science communication also forms part of the concept 'public service' (Boyer, 1996; Byrne, 1998; Holland, 1999) as well as 'community engagement' and 'social responsiveness' (Driscoll, 2008; South African Council on Higher Education, 2010; Strom, 2011), and 'engaged scholarship' or 'engaged research' (Doberneck, Glass & Schweitzer, 2010; Checkoway, 2013; Nhamo, 2013; Holliman & Warren, 2017). These terms all have one thing in common, namely that they relate to the communicative interactions between scientists and audiences external to the science community.

While many of these terms have similar meanings, they may be interpreted differently in different countries and institutions (Illingworth, Redfern, Millington & Gray, 2015) and there are subtle differences that stem from their different histories, philosophies, emphases and contexts (Burns *et al.*, 2003; Bucchi & Trench, 2014). For example, 'scientific literacy' is strongly associated with 'public understanding of science', with the main difference being that the former term is mostly used in the United States, and the latter is better known in Britain, with '*la culture scientifique'* more commonly

[6] For the purpose of this study, the terms 'outreach', 'science communication', 'public science communication', 'public engagement' and 'public science engagement' are considered essentially similar, and are used interchangeably.

used in France (Durant, 1993). People also use these terms in varied ways based on their own visions and ideals about the future relationship between science and society (Ogawa, 2013).

In addition to the multiple terms associated with public science communication, the field encompasses diverse models,[7] strategies and objectives. Therefore, scholars generally advocate for broad and inclusive definitions of relevant terms (Kreimer *et al.*, 2011; Bauer & Jensen, 2011; Davies, 2013a; Stilgoe, Lock & Wilsdon, 2014; Grand *et al.*, 2015). This definition by Horst, Davies and Irwin (2016:886) is an example.

> We define science communication as organised, explicit, and intended actions that aim to communicate scientific knowledge, methodology, processes, or practices in settings where non-scientists are a recognised part of the audiences.

Since the mid-1990s, the scope and diversity of public science engagement platforms have surged (Stilgoe *et al.*, 2014), resulting in a vast array of activities that may count as public science communication. This includes public talks, popular science writing, science theatre, science–art collaborations and public participation activities, such as citizen science and consensus conferences. These activities take place at science centres and festivals, museums and other cultural venues, science cafés, public spaces, such as shopping malls, parks and schools, as well as via online interfaces. Science content in the mass media and social media remains a crucial component of making science publicly visible, and science also finds its way into fiction, advertising, documentaries and feature films (McCallie *et al*., 2009; Kreimer *et al.*, 2011; Bauer & Jensen, 2011; Qi & Fujun, 2012; Dudo, 2013; Davies & Horst, 2016).

The diversity of interactions and audiences relevant to public science engagement is well illustrated at the Centre for Brain Research in New Zealand. Here, researchers connect with audiences ranging from young children to research funders via diverse activities, including storytelling, focus groups, public talks, school visits and fundraising events (France, Cridge & Fogg-Rogers, 2015). The variety and diversity in forms and formats of public engagement are also highlighted in a literature review by Grand *et al*. (2015), which includes references to earlier studies where up to 100 participatory activities and about 1 500 different engagement initiatives were recorded.

A general trend observed in public science communication over the last few decades is the shift away from top-down approaches designed to promote science uncritically, in favour of dialogue and interaction where scientists also listen to and learn from the public (Leshner, 2007; Davies, 2011; Phillips, 2011; Van der Sanden & Meijman, 2012; Claessens, 2014; Smallman, 2014).

The origins and definitions of key concepts are discussed briefly on the next pages.

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[7] In the context of public science communication, the 'model' of communication refers to the "mental construction of relations between the actors in the communication process" (Bucchi & Trench, 2014:3).

1.6.1. Science popularisation

Popularisation of science has its origins in the 19th century when science became so specialised that it needed to be translated for the public (Weingart & Guenther, 2016). It was inspired by a devotion to general enlightenment and to the production of knowledge for the common good (Bensaude-Vincent, 2001; 2009).

Researchers define science popularisation in a number of ways, mostly related to "the transmission of scientific knowledge from scientists to the lay public for purposes of edification, legitimisation and training" (Whitley, 1985:3). For Yoxen (1985), popularisation is about translating complex and esoteric ideas into everyday terms, but also about sharing images of science and the way scientists operate. The Chinese definition of science popularisation, as captured by the 2002 Law of the People's Republic of China on Popularization of Science and Technology (Qi, Xuan & Fujun, 2013), is broad and inclusive, namely to "popularize scientific and technological knowledge, to advocate scientific methods, to communicate scientific thoughts and to promote scientific spirit".

Looking at popularisation as a process that starts within science, Lievrouw (1990) describes it as the stage of scientific communication when a particular idea in science becomes part of the everyday public discourse, mostly via mass media channels. In contrast, Hilgartner (1990) has a more holistic view of popularisation, suggesting that it encompasses a spectrum of activities stretching from the technical laboratory across scientific articles and papers, seminars and books through to mass media accounts. In other words, there is a continuum of knowledge between experts and lay people. Bauer and Jensen (2011) agree that there is no definite point where science ends and popularisation begins.

Because science popularisation is often framed as an activity aimed at non-experts, which requires no particular expertise on the part of its audience (Bell & Turney, 2014), it is sometimes criticised as a paternalistic or deficit-style approach (Hilgartner, 1990). In line with this critical view of popularisation, Bensaude-Vincent (2001; 2009) points out that the term 'popularisation' has historically been used to assert the authority of professional science and its experts.

1.6.2. Scientific literacy

The idea of promoting scientific literacy in society took hold in the United States during the late 1950s, in all likelihood as a response to the concern of the American science community about public support for science in order to respond to the Soviet launch of Sputnik (Laugksch, 2000). Over the next decades, as people's ideas about science and society changed, the definition of science literacy transformed accordingly (Snow & Dibner, 2016).

Jon Miller (1983; 1998) has been credited with introducing the concept of 'scientific literacy'. His definition includes four elements, namely knowledge of basic textbook science; an understanding of scientific methods; appreciating the positive outcomes of science; and rejecting superstitious beliefs. This resonates with the idea that scientific literacy is about having sufficient knowledge and understanding of science in order to "deal effectively with matters scientific as they arise in the course of life” and to “make discerning judgements about its personal and social relevance” (Thomas & Durant, 1987:13).

However, many scholars maintain that scientific literacy is about more than content, and should also reflect knowledge about science as a process. Durant (1993) elaborate on three aspects of scientific literacy, namely

- knowing some science (basic knowledge, such as knowing that the earth revolves around the sun);
- knowing how science works (understanding the scientific method); and
- knowing how science *really* works (having the tools to judge science, and understanding the socio-political nature of science).

Snow and Dibner (2016) agree that scientific literacy has to do with achieving some level of familiarity with the enterprise and practice of science, including the understanding of science as a social process. As such, they argue, a scientifically literate society does not necessarily mean that every individual knows a specific set of things about science, but rather that people trust scientific expertise, are able to access scientific knowledge, as well as weigh and evaluate scientific outputs, and are also able to engage in civic debate and decisions about science.

Laetsch (1987) has a different view. Arguing that science literacy is fundamentally about understanding ourselves and our environment and the relationship between the two, the author argues that the ultimate rationale for promoting science literacy is humanistic, because knowing about the world around us enriches our lives.

Snow and Dibner (2016) concur that scientific literacy is a multi-faceted concept that operates differently in different contexts. Therefore, scientific literacy must be considered in the context of communities and societies, instead of viewing it as the responsibility of individuals. The ability of communities to become scientifically literate on a particular topic is particularly well illustrated when the knowledge becomes acutely relevant and important to them (Wynne, 1992; Wagner, 2007). Typically, this happens when people living in a particular area face a substantial challenge or environmental threat rooted in science, such as concern over contagious diseases (such as bird flu, swine flu or the Ebola and Zika viruses), hazardous chemicals in their water supply, or the potential impact of hydraulic fracking in their region.

Several scholars have highlighted the crucial importance of scientific literacy in developing countries where, particularly in poor, rural communities, basic knowledge of science can become a matter of survival (Lewenstein, Radin & Joubert, 2002). Equally, scientific literacy makes it possible for people to distinguish credible science from potentially dangerous pseudoscience (Allum, 2011) and to combat the social problems that are rooted in myths and superstitions (Miller, 1983; Manzini, 2003). As an example, Falade (2016) describes how pro-religious, anti-science views in Nigeria led to the banning of the oral polio vaccine in some parts of the country in the first years of the 21st century, leading to 5 000 new polio cases in those areas.

1.6.3. Public understanding of science

The 'public understanding of science' movement arose from the sentiment that an urgent need existed to address low levels of public scientific literacy and growing anti-science sentiments as revealed by quantitative surveys (e.g., Lewenstein, 1992a; Gregory & Miller, 1998; Bakuwa, 2015). In addition to measuring how much the public knew about science, researchers became interested in determining public attitudes towards science (Bauer *et al.*, 2007).

Scholars have deliberated at length about the meaning of the phrase 'public understanding of science' and its constructs, 'public', 'understanding' and 'science'. Which publics are included? Does 'understanding' refer to knowledge, or is it about public support? What needs to be understood? Does science itself need to be understood, or is it the process of science? (e.g. Turney, 1996; Miller, 2001; Miller, 2004; Bakuwa, 2015) Bauer and Jensen (2001) highlight the double meaning implicit in the phrase 'public understanding of science', arguing that it refers not only to the public's understanding of science, but also to the mobilisation of scientists and resources to engage the public around scientific issues.

Bauer *et al.* (2007) point out that efforts to promote public understanding of science were driven by the common-sense axiom 'the more you know, the more you love it', but the authors point out that empirical research has revealed that, especially in the case of contested science topics, it may rather be a case of 'familiarity breeds contempt'. A similar finding was illustrated 12 years earlier by Evans and Durant (1995:57) who state:

> Understanding of science is weakly related to more positive attitudes in general; but, more significantly, it is also associated with more coherent and more discriminating attitudes. Of particular importance is the finding that while knowledgeable members of the public are more favourably disposed towards science in general, they are less supportive of morally contentious areas of research than are those who are less knowledgeable. Although an informed public opinion is likely to provide a slightly more supportive popular basis for some areas of scientific research, it could serve to constrain research in controversial areas such as human embryology.

1.6.4. Science outreach

The term 'science outreach' is consistently associated with school/education-linked activities aimed at learners and/or teachers. It is generally defined as a one-way discourse in which scientists communicate their research to the public, with particular focus on schoolchildren and youth (Illingworth *et al.*, 2015). Typical outreach activities include scientists' involvement in school-based science clubs, tutoring, mentoring, judging science fairs and presenting teacher workshops (Andrews, Weaver, Hanley, Shamatha & Melton, 2005; Ecklund, James & Lincoln, 2012).

Some scholars define 'science outreach' more broadly, including activities aimed at the general public. For example, the term is defined as meaningful and mutually beneficial collaborations that enable learning beyond the campus walls, make new discoveries useful outside the academic community, and a service that directly benefits the public (Ray, 1999). Science outreach also encompasses public lectures, interactive forums, or popular press articles in which scientists communicate their research or broader scientific concepts to those outside the science community (Johnson *et al.*, 2014).

1.6.5. Informal science learning

Informal science learning, comprised of playful and meaningful learning that typically takes place outside formal classroom settings, happens in the course of daily life in places such as botanical gardens, zoos, aquaria, science centres and museums. These contexts focus on mutual learning, skills development and interaction, and recognise multiple perspectives on science, ethical concerns about science and the cultural nuances of knowledge (McCallie *et al.*, 2009; Gilbert, 2010; Crone, Dunwoody, Rediske, Ackerman, Petersen & Yaros, 2011; Sánchez-Mora, 2016).

As far as informal learning is concerned, Bell, Lewenstein, Shouse and Feder (2009) distinguish between everyday experiences (like walking in nature or watching a sunrise), designed settings (for example, a visit to a planetarium or a science play), programmes (such as participating in a citizen science project), and learning science from the mass media (print, television, films, etc.). The authors note that these informal learning environments offer particular opportunities for inclusion of culturally, socially and linguistically diverse communities.

1.6.6. Civic engagement

Civic scientists actively take their knowledge into the public arena (Clark & Illman, 2001; Greenwood & Riordan, 2001; Kyvik, 2005). They inform communities, but also listen to and learn from them (Lane, 1999). Mathews *et al*. (2005:162) state:

> A civic scientist recognizes herself as one part of a whole that is far more complex and rich than a single scientific discipline, and with much more to offer or consider than solely a scientific perspective.

Civic engagement is defined as "those activities which individual academics undertake which involve interaction with the non-academic community and are related to academic expertise" (Bond & Paterson, 2005:338), including activities such as participating in public debate, giving advice to policymakers, interacting with journalists and even giving expert testimony in court.

1.6.7. Public engagement

While clearly similar to civic engagement, the notion of 'public engagement' has gained popularity as a prevalent term to describe a wide range of science and society interactions. It is increasingly recognised as a relevant mandate, "as well as a responsibility", for research institutions (Bucchi & Trench, 2014:5). However, despite the growing normative acceptance of public engagement within the culture of science, there are many different views about its audiences and aims (Illingworth *et al*., 2015). Given the variety of forms and contexts of public science engagement, it is problematic to define and demarcate the concept, a challenge that is further exacerbated by the current trend towards digital engagement (Schäfer, 2009; Trench, 2009; Kouper, 2010; Bauer & Jensen, 2011; Grand, Holliman, Collins & Adams, 2016). In this regard, Davies (2013a:704) states, "it is somewhat disingenuous to speak of a single meaning for public engagement. Instead there are a thousand tiny origin myths, each tied to different places and people".

Davies (2013b) identifies two key models for engagement: an education model focused on communicating science aiming for positive effects on research funding and people's lives, and a participation model which emphasises the active involvement of the public in research.

'Public engagement' is frequently used as an umbrella term for a range of activities that engage the public with research – from science centres or festivals, to public dialogue and consultation (Research Councils UK, 2011). Some researchers include school-based interactions between scientists and children as part of public engagement (Kreimer *et al.*, 2011), but others limit it to activities aimed at adults outside of a classroom setting (Besley, 2015b).

When contrasting public communication and public engagement, the former is often positioned as a one-way process, and the latter as a two-way interaction (Rowe & Frewer, 2005; Holliman, Collins, Jensen & Taylor, 2009). The deliberative and mutually beneficial nature of public engagement is emphasised (Illingworth *et al.*, 2015; AAAS, 2016). By implication, public science communication and outreach may be regarded as ad hoc, while public engagement is seen as a deliberate and structured activity that seeks public input via dialogue, and which therefore benefits both science and society. Jensen and Holliman (2015:56) corroborate this view by stating:

> There is a heterogeneous community of practice operating in the space between what can be characterised as deficit-informed 'science outreach' – aimed primarily at increasing scientific literacy – and dialogue-informed 'public engagement' seeking to foster productive exchanges between scientists and other stakeholders (including members of the public).

The prevailing expectation on the part of the public that the scientists should consult the public about developments in cutting edge science, is accentuated in a study by Scheufele, Xenos, Howell, Rose, Brossard and Hardy (2017).

The notion of 'upstream engagement', with its emphasis on purposeful dialogue between experts and lay publics at an early stage of the knowledge production process, has elicited much discussion and debate (Wilsdon & Willis, 2004; Rogers-Hayden & Pidgeon, 2007). Upstream engagement aims to increase social inclusion and public participation in science by making the public a key player and democratic partner in the regulation of research, as well as to broaden the perceptual horizons of science by responding to the social, cultural and ethical concerns of the public (Wilsdon, Wynne & Stilgoe, 2005). The public is mobilised to confirm the legitimacy of science and the credibility of scientists, thereby helping to restore trust and cohesion between expert and non-expert communities (Fiorino, 1990), and is integrated into research processes as a co-producer for social and economic good (Holliman & Jensen, 2009). However, while public input may aid effective science policy development and may help to avoid public opinion fiascos about science, Hornig Priest (2009) cautions against the assumption that public engagement provides insurance against public opposition to emerging technologies.

Smallman (2014) reflects on a shift in the way academics view public dialogue: from a position of advocating and championing dialogue with the public, to a more critical view of how dialogue is achieved and whether it is effective. Irwin, Jensen and Jones (2012) point out that criticism lies at the heart of science engagement practice and should be viewed as a creative process that prevents stagnation and enables productive reflection on public-science interactions.

1.6.8. Public participation

"The public expects to participate, and indeed must participate, in determining the directions of science; elitism is no longer tolerable – it is no longer safe", argues Goodell (1977:8).

Public participation in science has been described as a "stronger form of engagement" because of its association with the governance of science and participatory democracy (Bucchi & Trench, 2014:5). Here, the focus is on allowing the public to become part of the production of new knowledge, rather than on public education or efforts to legitimise science policy.

Some scholars emphasise that public participation is a way to solicit the views of the public, rather than their active participation in knowledge production. For example, Rowe, Marsh and Frewer (2004:88-89) define public participation as follows:

> Public participation may be loosely defined as the practice of consulting and involving members of the public in the agenda-setting, decision-making, and policy-forming activities of the organisations or institutions responsible for such functions.

Bonney et al., (2009) position public participation in research as an informal learning activity that provides multiple opportunities for increasing scientific literacy – i.e. closely related to the concept of 'citizen science'.

The definition provided by Bucchi and Neresini (2008:449) presents public participation in science as a process that involves multiple steps along the science policy and knowledge production trajectory:

> Public participation may be broadly defined as a diversified set of situations and activities, more or less spontaneous, organised and structured, whereby non-experts become involved, and provide their own input to agenda setting, decision-making, policy forming, and knowledge production processes regarding science.

Bucchi and Neresini (2008) propose a framework for public participation in science and technology. This includes so-called sponsored activities (such as referenda, science shops, public hearings or inquiries, public opinion surveys, negotiated rule-making, consensus conferences, and citizen juries), as well as spontaneous forms of participation (for example public protests and patient associations). Bakuwa (2014) argues that non-experts could play a crucial role in science governance, and that they are able to contribute valuable knowledge (that scientists don't have) to research.

Irwin (2006) highlights another objective of public participation and dialogue – namely to win back the trust and support from people who are sceptical about the way governments and institutions have communicated issues of risk in the past. Reflecting on public engagement around the issue of genetically modified food in the UK, Irwin finds, however, that “the link between engagement and enhanced trust can be decidedly tenuous” (2006:314), leading him to conclude that it would be naïve to present public participation as an antidote for public concerns and scepticism over societal implications of new technological developments. Irwin further points out that public dialogue exercises raise certain expectations on the part of the public about how their input will affect policy processes, and that people may be disappointed when these expectations are not met.

As can be expected, public participation in science also meets with scepticism and criticism, since the idea of allowing (or even asking) the public to become part of the scientific process may be perceived to be in direct contrast with scientists’ views about the notion of expertise and the authority of science. For example, Thompson, Barber, Ward, Boote, Cooper, Armitage and Jones (2009) show that researchers generally perceive some value in public input, but still feel hesitant and uncomfortable about this new way of doing research. Van der Auweraert (2008) finds that scientists disagree about the rights of lay people to participate in science and see risks in involving non-experts., Watermeyer (2012) demonstrates that researchers show limited support for ‘upstream engagement’, i.e. the notion of involving public audiences early on in the research cycle. Along the same lines, Irwin (2006:301) casts doubt on institutional claims of a shift towards transparency and open, two-way dialogue with society, noting that “relations of professional power are not likely to disappear simply as a consequence of publicly stated recommendations”. Irwin (2006:2203) notes that, in terms of scope and scale, public engagement initiatives remain minor and restricted when compared with the bulk of institutional science that remains “largely insulated from shifts in governance philosophy”.

Durodié (2003:85) contends that efforts to include lay values in deliberations about science are merely an attempt to restore some legitimacy to the scientific enterprise through forced dialogue, and comprise nothing more than “an act of moral and intellectual cowardice”. The author is of the opinion that the inclusion of lay opinion in decision-making about science devalues scientific evidence and demoralises scientists, while it also patronises the public.

Based on research into public understanding of science over a period of 25 years, Bauer *et al*. (2007) trace the development of these issues over three paradigms, associated with specific attribution problems and proposals for research, as illustrated in Table 1.2.

Table 1.2: Paradigms for public understanding of science

Period	Attribution problems	Research
Science literacy 1960s onwards	Public deficit related to a lack of knowledge	Literacy measures; education
Public understanding After 1985	Public deficit related to attitudes and education	Knowledge and attitudes Attitude change Image marketing
Science and society 1990s to present	Deficit related to a lack of public trust and experts' notions of the public, leading to a crisis of confidence in science	Participation Deliberation Mediators Impact evaluation

Source: Adapted from Bauer *et al*. (2007)

1.7. Ways to categorise public science communication

In order to help clarify some of the perceived confusion around the typology and nomenclature in the field of public science communication, scholars have proposed ways to group related science communication activities into meaningful categories. For example, public science communication can be categorised according to traditional communication activities such as media engagements and public talks; new communication platforms emerging in online environments (social networks); and novel in-person opportunities, such as science–art collaborations and citizen science (Besley, Dudo & Storksdieck, 2015). It is also possible to draw a line between self-initiated science communication activities (e.g. a scientist writing a popular article) and mediated communication (e.g. a scientist being interviewed by a journalist).

Depending on the context, it may also be useful to categorise public communication activities based on one or more of the following characteristics: objective, target publics, flow of information, and level of interaction. These categories are briefly discussed below.

1.7.1. According to target publics

By nature, public communication of science is aimed at people who are outside the science arena, but these public audiences are as "multifaceted and unpredictable as the individuals that compose it" (Burns *et al*., 2003:184). The public is made up of individuals and groups with different backgrounds, interests, experiences, affiliations, belief systems, world views, economic circumstances, genders, sexualities, etc. Each public segment has its own characteristics that demand different communication strategies (Kyvik, 2005), based on the needs, interests and constraints of the participants (Nelkin, 1996). Consequently, it is vital to understand the target audience (for example their level of interest, technical competence and familiarity with the topic) when designing science communication activities. Whitley (1985:19) emphasises the need to view science communication from the audience's perspective, "Popularisation has to fit in to the audiences' framework and concerns, rather than simply expressing the researchers' priorities and approaches."

Bunders and Whitley (1985:62) underline the need to segment audiences for science, adding that it would be a 'Herculean task' to convey scientific knowledge to a large, vague, undifferentiated and unorganised mass. Borchelt (2001:200) concurs that the notion of a general audience for science is misplaced, by stating:

> There is no such thing as a general audience for science and technology communication; rather, there are many people with many different uses for science and technology information and many levels of understanding with which to deal … [and] … there is no such thing as a one-size-fits-all public communication message for a mythical lay public. Single messages designed to reach all public audiences typically end up reaching none of them very well.

Einsiedel (2004, 2007) warns against thinking that the public can be divided into static segments, adding that people assume different roles at different times and in different contexts. This will influence how they respond to science.

Despite the general agreement that public science communication is aimed at non-expert audiences, scientists also form part of the lay public when it comes to fields outside their own areas of specialisation (Crettaz Von Roten, 2011; Chikoore, Probets, Fry & Creaser, 2016; Entradas & Bauer, 2016). Furthermore, it is not always possible to draw a line between communication aimed at peers and that aimed at lay people. Notably, the blurred boundaries between scientific and public communication could contribute to a more efficient transfer of knowledge between science and society (Peters *et al.*, 2014). Acknowledging science communication as an intra- and extra-scientific endeavour, Shinn and Whitley (1985:viii) propose the concept of scientific exposition, encompassing a "continuum of methods" used to exchange scientific ideas "within research and far beyond".

1.7.2. According to the flow of information

One way of categorising science communication is to consider the direction of information flow, which makes it possible to group activities on the basis of one-way, two-way or multi-directional flow of information (Rowe & Frewer, 2005; Johnson *et al*., 2014). Historically, public understanding of science was characterised by a one-way flow of information from an expert to a lay audience (Brossard & Lewenstein, 2010), while public engagement activities were generally reciprocal in nature, characterised by interaction, participation and dialogue between scientists and diverse public audiences and typically aimed to give the public an opportunity to voice their views and concerns about science (Research Councils UK, 2011). The one-way flow of information (the so-called 'deficit model') is based on the idea that the public will uncritically accept the information that experts pour into their empty heads. In the real world, however, audiences are critical and communication is likely to be a blend of dissemination (one-way flow of information) and interaction (two-way or multi-directional exchanges of information). Therefore, several models of public science communication co-exist[8] (Miller, 2001; Sturgis & Allum, 2004; Brossard & Lewenstein, 2010). Policymakers and communication practitioners may not like the idea that one-way, top-down science communication has been found to be insufficient and ineffective, since meaningful public dialogue is often hard to achieve (Irwin, 2009).

Hornig Priest (2007:145) cautions against excessive emphasis on how scientific information travels from within the science community outward. Instead, she emphasises the dynamic and personal nature of science communication as follows:

> Science communication is not just about translation (or even about diffusion), but about the dynamics of the ways that technically complex information – often (as with climate change) information with urgent and vital policy implications – reaches diverse audiences who (as active audiences) apply their own ethics, values, and beliefs to its understanding.

1.7.3. According to the platform and level of interaction

Public engagement with science may be divided into three main categories according to the platforms or media that are involved, namely traditional mass media, including newspapers, magazines, radio, and television; live or face-to-face events, such as public lectures and science cafés; and online interactions, for example blogging and tweeting (Bultitude, 2011). Alternatively, science communication can be grouped according to the three main levels where these activities take place, namely policy level, institutional level and at the level of individual researchers (Entradas & Bauer, 2016).

1.8. The importance of objectives

The most effective approach when communicating science depends on what the communicator is trying to achieve, i.e. the communication objectives. It is essential to clarify whether the objective is to inform, such as to entertain, to educate, to inspire, to impress, to persuade, to influence opinion, to build trust, or to get feedback (there are many more possible objectives). Each objective demands different skills and requires a distinct approach (National Academies of Sciences, Engineering and Medicine, 2017). Moreover, unless these objectives are clear beforehand, it is not possible to determine later whether a particular activity was successful.

Science communicators typically pursue a wide and diverse set of objectives (or goals), including defending science (Hartz & Chappell, 1997), restoring public trust in science (Illingworth *et al.*, 2015), empowering citizens to engage with science (Rowe & Frewer, 2005), obtaining meaningful public input into science policy processes (Borchelt & Hudson, 2008), and aiming for education, entertainment and cultural significance (Rennie, 2001). For example, Sánchez-Mora (2016:1) lists the following objectives:

[8] Many authors have commented on the persistence of the deficit model in science communication. For example, Irwin (2009:8) says it is all but dead, ascribing to it a "zombie-like longevity, refusing to lie down in its grave, and lurking within many attempts at science communication".

> […] entertaining, informing, enabling, educating, raising awareness, empowering or creating a social scientific and technological knowledge, which can eventually lead to the creation of what is referred to as scientific culture.

The UK National Coordinating Centre for Public Engagement (NCCPE, 2016) describes the objective of public science engagement as follows:

> Done well, it generates mutual benefit, with all parties learning from each other through sharing knowledge, expertise and skills. In the process, it can build trust, understanding and collaboration, and increase the sector's relevance to, and impact on, civil society.

It is not uncommon for science policymakers to suggest a combination of promotional, educational, dialogic and altruistic motivations when they state the goals of public science communication. For example, the public Research Councils UK (People Science & Policy, 2002:3) promote the following dialogue goals:

- to promote an awareness of science as 'part of the fabric of society';
- to promote an individual organisation;
- to demonstrate public accountability;
- to recruit the next generation of scientists and engineers;
- to gain acceptance of science and new technologies; and
- to support sound and effective decision-making.

Similarly, in a proposed agenda for future science communication research, the National Academies of Sciences, Engineering and Medicine (2017:1-2) in the United States, lists the following key goals:

- sharing the findings and excitement of science;
- increasing appreciation for science as a useful way of understanding and navigating the modern world;
- increasing knowledge and understanding of the science related to a specific issue;
- influencing people's opinions, behaviour and policy preferences; and
- engaging with diverse groups so that their perspectives about science related to important social issues can be considered in seeking solutions to societal problems that affect everyone.

The 2014 science engagement framework of the South African government (DST, 2014), likewise lists a combination of strategic (promotional) and engagement aims. Some of these aims focus on promoting and profiling science and its achievements in order to attract public interest and support, namely "to popularise science, engineering, technology and innovation as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers" (DST, 2014:3); and "to profile South African science and science achievements domestically and internationally, demonstrating their contribution to national development and global science, thereby enhancing its public standing" (DST, 2014:4). These aims contrast with another aim, namely "to develop a critical public that actively engages and participates in the national discourse of science and technology to the benefit of society" (DST, 2014:4) where the emphasis is on the need for open and timely public dialogue around disputed developments and issues in science.

When it comes to how these science communication goals play out in the real world, science communication scholars have pointed out that individual researchers typically prioritise justifying, promoting and defending research (Watermeyer, 2012), while institutions overemphasise the uncritical promotion of science in order to gain acceptance and support for science, while neglecting critical dialogue with society. Lewenstein (1992a) claims that when role players in science communication talk about public understanding of science, they often really mean improving the public's appreciation of the benefits that science brings to society. Consequently, the definitions and actions of the role players focus on promoting science, and hardly ever on questioning science. Borchelt (2001) agrees that the science community mostly fails to differentiate between understanding of science on the one hand, and building appreciation for research organisations on the other – often touting reputation-enhancing communication efforts as programmes aiming to advance public understanding.

Claessens (2014:1–2) argues that research organisations typically present an unfocused mix of science relations and reputation-building activities, while neglecting "real communication" in the sense of open dialogue with society based on high-quality information about science, which "deeply handicaps science–society relationships and the public acceptance of advancements in science and technology".

Along the same lines, Irwin (2014:169) argues in favour of so-called 'third-order' thinking in science communication, stating:

> Science communication should not mainly aim at persuading citizens and in particular young people to embrace science and technology in a rather unquestioned manner, but rather support them in becoming reflexive members of contemporary knowledge societies through caring for broader science–society issues.

Regarding the tensions between celebrating science and evaluating science critically, Lewenstein (2016:6) adds his voice to the call for more reflection on the part of scientists and science communicators. He makes a strong case that the public communication of science and technology is, first and foremost, a tool of democracy. He adds:

> I think that each of us, as a practitioner or as a researcher, needs to be aware of the tensions between democracy, expertise, and science communication. We need to be attuned to times when those tensions affect our work. We need to be aware of it when the source of our funding shapes the stories or exhibits or demonstrations or research that we produce. We need to be questioning what, exactly, our expertise is in. We need to think about what democracy means in our own countries and how our work contributes to that democracy.

Notably, none of these high-profile science organisations listed above include the objective of attracting funding, and only one of them refers to the promotion of a specific organisation. However, the objective of raising money and building institutional reputations is highlighted by scholars as important drivers of the growing science communication enterprise (e.g. Shinn &

Whitley, 1985; Koh, Dunwoody, Brossard & Allgaier, 2016; Weingart & Guenther, 2016), while scientists themselves readily admit that they communicate with public audiences in order to raise funding for their research (Peters *et al*., 2008a; Allgaier, Dunwoody, Brossard, Lo & Peters, 2013a; Marcinkowski, Kohring, Furst & Friedrichsmeier 2014).

1.9. Scientists as public communicators, and even advocates

For scientists, communicating their work via journals and conferences is the basis for recognition and building an academic career (Bensaude-Vincent, 2009). The obligation to communicate with their peers is clear, but their role to communicate with the public is more vague and uncertain (Kyvik, 2005; Crettaz Von Roten & Goastellec, 2015). Most scientists are first and foremost focused on the generation of new knowledge, rather than its applications and dissemination, and they may therefore find it problematic to be cast in the role of public expert (Peters, 2014). The esoteric and highly specialised nature of modern science makes it hard for scientists to find connections with people's everyday lives in order to make the work relevant, accessible and meaningful to journalists and lay people. However, consensus that scientists have a responsibility (a moral duty even) to engage with the public and reflect on new advances in science, seems to be growing (Stilgoe & Wilsdon, 2009). As suggested by Gregory (2001), scientific knowledge is special knowledge and special powers rest with those who have it.

Clearly, scientists occupy a central position in the process of public science communication, and their direct involvement is vital in achieving and sustaining meaningful connections between science and society (Gregory & Miller, 1998; Borchelt, 2001; Miller, 2001; Burns *et al.*, 2003; Bauer & Jensen, 2011). Face-to-face exchanges between scientists and non-experts, without any mediators or filters, open up dialogue and nurture trust in science (Riise, 2008). Consequently, the ability to communicate new evidence to broad public and policy audiences is increasingly hailed as an essential skill and a central requirement for influence and leadership in science (Gieryn, 1983; Greenwood & Riordan, 2001; Parsons, 2001; Waterton, 2005; Baron, 2010a,b; Smith *et al*., 2013; Wright, 2015), and scientists in leadership positions are expected to interact with the media regularly (Peters *et al*., 2008a). The importance of scientists' personal participation in public communication is further accentuated by Fahy and Lewenstein (2014:84) who argue that the person behind the science is a "powerful way to humanise science" and to "provide the dramatic core for good stories".

Besley & Dudo (2017) acknowledge that scientists are not the only ones who can communicate about science, but makes a strong case for the central role of scientists in public communication efforts in order to ensure that scientists actively participate in information exchanges with public and policy audiences.

Recognising the significance of scientists' willingness to participate (Ruth, Lundy, Telg & Irani, 2005), policymakers, funders and science leaders call on scientists repeatedly to step up their engagement with society (Bodmer, 1985; Wolfendale Committee, 1995; DACST, 1996; House of Lords, 2000;

Cicerone, 2006; Leshner, 2006; Leshner, 2007; Cheng, Claessens, Gascoigne, Metcalfe, Schiele & Shi, 2008; Friedman, 2008). They urge scientists to be more accessible to the outside world, participate in public discourse and integrate public engagement into their research (e.g. Turney, 1996; MORI, 2001; Marincola, 2003; Cloern, 2013), particularly in developing countries (Khanna, 2001; Malekian, Omar, Abdullah & Malekian, 2011; Dickson, 2012).

However, many scientists struggle to cope with these communication demands due to a suite of perceived obstacles and risks (Brown, Propst & Woolley, 2004; Cheng *et al*., 2008; Davies, 2008; Kohut, Keeter, Doherty & Dimock, 2009; Neresini & Bucchi, 2011; Grand *et al*., 2016).

Scientists are frequently framed as poor communicators, who are unable to explain their jargon-laden findings to lay audiences (Hartz & Chappell, 1997; Weigold, 2001; Treise & Weigold, 2002). Their communication shortcomings may be the result of personality types (Goodell, 1977) or a lack of skills (Chalmers, 2009). Furthermore, the sheer volume and pace of knowledge production make it hard for scientists to get attention for their work (Suleski & Ibaraki, 2010), while ongoing changes in the media ecosystem demand specialised skills from those who wish to make their research publicly visible (Brossard & Scheufele, 2013).

On the other hand, as creators of new knowledge, scientists are in demand as media sources and public discussants and some respond well to these expectations. Repeated surveys show that many scientists can and do interact with the public, directly and via the media, and that these interactions are more frequent and less problematic than commonly assumed (Dunwoody & Ryan, 1987; DiBella, Ferri & Padderud, 1991; Pearson *et al*., 1997; MORI, 2001; Bond & Paterson, 2005; Jensen, Rouquier, Kreimer & Croissant, 2008; Peters *et al*., 2008b; Torres-Albero *et al*., 2011; Searle, 2013; Pew Research Center, 2015a; TNS-BMRB, 2015; Massarani & Peters, 2016).

There is considerably more reason for concern about public science engagement in the developing world, where interactions between scientists, journalists and the public remain less common and more troublesome compared to the developed world (Gething, 2003; Appiah, Gastel, Burdine & Russell, 2015; Ndlovu, Joubert & Boshoff, 2016) and where structural and cultural barriers continue to limit scientists' ability to connect with ordinary people (Bakyawa, Devlin, Serwadda & IJsselmuiden, 2013; Hin & Subramaniam, 2014; Bakuwa, 2015).

Furthermore, there is widespread consensus that science is becoming increasingly complex, controversial and political in nature (Tsfati, Cohen & Gunther, 2011; Scheufele, 2014; Burns, 2015; Suhay & Druckman, 2015). Consequently, societal debates about science often focus on its political, ethical, moral, legal and economic implications, rather than the science itself (Scheufele, Corley, Shih, Dalrymple & Ho, 2009) and the public's response to science depends on social and political contexts (Sturgis & Allum, 2004). Therefore, scientists who speak out in public often find themselves negotiating a fine line between public communication, advocacy and even activism, and may face a series of tensions and trade-offs (Sarkki, Niemelä, Tinch, Van den Hove, Watt & Young, 2014).

Quoting the example of how a letter from Einstein to President Roosevelt, written in 1939, led to the Manhattan Project,[9] Scheufele (2014) argues that scientists have long played policy advisory roles and are therefore often the targets of partisan criticism, leading to the conclusion that science communication is inherently political. By contrast, Peters (2014) draws a distinction between the roles of scientists as communicators versus policy advisors.

Scientists, themselves, are ambiguous about their roles when it comes to advocacy and lobbying. Some view advocating for support or lobbying for funds as inappropriate, crass and distasteful, and fear that it will compromise the integrity of their work or the valued norm of disinterestedness (Gascoigne, 2008). These scientists may therefore purposely avoid becoming visible in public life (Johnson *et al*., 2014). On the other hand, scientists realise that the value of their work is not necessarily self-evident and that they need to make a case for funding against competing demands and anti-science sentiments. Consequently, scientists are urged to become advocates for evidence-based positions (Nelson & Vucetich, 2009; Vucetich & Nelson, 2010), and scientists are looking for ways to connect with policymakers and be heard (Gascoigne, 2008). According to Scheufele (2007:48), "Scientists are not in the business of selling science, but they should not undersell it."

The debate about the appropriateness of advocacy in science communication begs the question whether communication about science is ever really neutral. Some authors claim that the ultimate goal of most science communication is inherently strategic in nature and, therefore, interested and persuasive. Such authors say that scientists are trying to reinforce or change a given behaviour or belief (Fishbein & Cappella, 2006; Dudo & Kahlor, 2017). Maddox, *Nature* editor for 22 years (1966–1973 and 1980–1995), claims that persuasion is the essential missing element in most popular science writing, and urges scientists to accept the importance of actively persuading readers of the importance and value of their work (Shortland & Gregory, 1992:10).

On the topic of neutrality in science communication, Gregory (2016:2) points to three key outcomes of scientific studies about the nature of science communication:

- science is not, and never has been, neutral;
- science communication is part of the social continuum of the practice of science; and
- science communication is, in the first place, communication and therefore only marginally different from other forms of communication.

Therefore, Gregory argues that science communication itself is not neutral, nor is it tainted (because it has never been in a pure state before). Rather, "science communication is simply interested, as are most, if not all, of our communicative acts" (Gregory, 2016:2).

1.10. Public visibility in science

Instead of being derided as geeks or nerds, scientists should be seen as courageous realists and the last great heroic explorers of the unknown. They

[9] A project focused on developing atomic weapons in the United States before Nazi Germany could do so (Lewenstein, 1992c)

> ***should get more money, more publicity, better clothes, more sex and free rehab when the fame goes to their heads.***
> *(Matthew Chapman, quoted in Mooney & Kirshenbaum, 2009:v)*

Since the current study focused on the science communication behaviour of publicly visible scientists in South Africa, it was necessary to interrogate the concept of public visibility in more detail.

There is a wide spectrum of degrees and types of visibility within and outside science, and it is difficult to define exactly when a scientist can be considered to be publicly visible. Some scientists may become publicly visible at a regional level, while others become household names around the world and become a part of modern celebrity culture (Fahy & Lewenstein, 2014).

Goodell (1975:9) reflects as follows on the innovative and adaptive nature of visible scientists:

> Today's visible scientists are those who are adjusting to the modernization of science communication, to the changes in communication technology and in the scientific community. In the survival struggle of our rapidly evolving communication media, they are the scientists who are adapting. They are exploring new vehicles for influence, new channels for communication between science and society. Fashioning new rules of scientific decorum, they are, consciously or unconsciously, experimenting with ways to provide the kind of input the public now demands.

Bucchi (2015) notes that the attention of colleagues (and of the media and the non-expert public) is increasingly a scarce resource for which scientists compete. He therefore describes highly visible scientists as those who have entered a narrow circle, "that elite of researchers on whom awards like the Nobel Prize confer almost unassailable prestige and a reputation able to open every door" (2015:240). In an increasingly competitive research arena, Bucchi contends there are only a small number of highly visible scientists at the top of a pyramidal structure of visibility. These are the science superstars, somewhat similar to stars in the world of entertainment and sport. As such, visible scientists are increasingly recognised as influential leaders with a special role in making science part of mainstream society and the power to effect changes within science (Baron, 2010a; Fahy & Lewenstein, 2014; Bucchi, 2015; Fahy, 2015).

1.10.1. The link between public and academic visibility

Visibility within science primarily results from publication[10] and citation rates, while public visibility is inextricably linked to a high media profile (Goodell, 1977; Fahy, 2015). Rödder (2012:160) describes visible scientists as "occupants of a boundary role at the science–media interface". Public visibility also attracts the attention of peers, and leads to increased recognition within the scholarly arena (Johnson *et al*., 2014). This is illustrated by a seminal study of science stories published in the *New York Times* (Phillips, Kanter, Bednarczyk & Tastad, 1991). Similarly, the strategic use of Twitter has the ability to attract scientific attention and boost citation rates (Liang *et al*., 2014). Several

[10] Scientists may also become visible to journalists as a result of publishing in top journals, since many specialist journalists monitor journals, such as *Nature* and *Science*, and these journals also boost the visibility of articles via their own public relations (PR) efforts. However, the willingness of scientists to collaborate with PR staff and respond to media enquiries will influence their resulting public profiles.

studies agree on the correlation between tweets and citations, for example Eysenbach (2011) found that highly tweeted articles were 11 times more likely to be highly cited than less-tweeted articles and concluded that tweets within the first three days after an article was published could predict whether an article would be highly cited or not, while Finch, O'Hanlon and Dudley (2017) suggest that Twitter activity may anticipate or even drive citations. Other studies point to a more tentative, indirect link between Twitter acitivity and citations (Ortega, 2016; Peoples, Midway, Sackett, Lynch & Cooney, 2016; Tonia, Van Oyen, Berger, Schindler & Künzli, 2016), while some authors found only weak correlations between tweets and citations – see for example Haustein, Peters, Sugimoto, Thelwall and Larivière (2014) and De Winter (2015).

Some studies furthermore show that 'visibility feeds visibility', i.e. scientists who regularly participate in public communication of their work gain future visibility via the self-reinforcing feedback loops of media attention (Peters, 2008) and the process of reciprocal intensification[11] (Marcinkowski, Kohring, Furst & Friedrichsmeier, 2014).

Moreover, scientific controversies that play out in the mass media stimulate debate within academic circles, providing another structural connection between public and academic visibility (Bucchi, 1996; Weingart & Pansegrau, 1999; Wagenknecht, 2012). Bucchi (1996:384) concludes that the communication of science occurs simultaneously at different levels in the scientific and public arena "which continuously exert reciprocal influence on one another", confirming the notion that public visibility also has implications for recognition within academic circles.

Biswas and Kirchherr (2015) argue that, because of the societal impact of public visibility, scientists should be rewarded for becoming publicly visible. The authors contend that the influence of most peer-reviewed publications, even within the science community, is miniscule, and that policymakers do not read long, technical journal articles. As such, a presence in popular media is essential to influence public debate and decision-making.

1.10.2. Scientists' ambivalence about public visibility

While the science community may have become more accepting of public visibility, some scientists remain concerned about the potentially damaging effects of a high public profile on their scientific reputations (Rödder, 2012). Their concerns are intensified by apprehensions about the risks presented by social media and the rise of public relations (PR) approaches in science communication that have highlighted how some scientists compete for public attention (Marcinkowski & Kohring, 2014; Weingart & Guenther, 2016). The tensions between increasing expectations to engage with public audiences and lingering reservations about the potential consequences of doing so sustain scientists' ambivalence about public visibility.

Forty years ago, Goodell (1977:90) argued, "the scientific community is a morass of conflicting and changing attitudes on the subject of communicating with society", and that this was fuelling

[11] Marcinkowski *et al*. (2014:75) explain that some scientists become "attractive addresses" for both journalists and PR professionals looking for "publishable statements".

scientists' doubts regarding public prominence. The author points out that certain moral, political and social concerns encourage scientists to participate in public communication, but other (often more pressing) political, social and psychological needs militate against it. Often, scientists' immediate needs are best served by keeping quiet. Goodell (1977:91) quotes Philip Abelson, former publisher of *Science,* as saying that "the balance sheet of their own self-interest nets out in favour of silence." She furthermore notes that there is a "hole" in scientific norms about how scientists should relate to society, adding (Goodell, 1977:90):

> On the one hand, it is fairly well accepted today that scientists must do some public relations work, some popularizing, in order to loosen the public purse strings. This view increases as funds decrease and fears of anti-science sentiment grow. Scientists, previously afraid they would be misunderstood if they *were* involved with popular communication, now find they are misunderstood because they are *not* … On the other hand, because of the emphasis in science on the nobility and necessity of doing basic research, activities such as popularizing are viewed as a little lowly, distracting at best, demeaning at worst.

Despite indications that the science community is becoming more tolerant towards scientists who become publicly visible, the view that a high public profile may tarnish a scientific career persists. Rödder (2012:174) concludes:

> To be visible – meeting the expectations to communicate with extra-scientific publics – and to be a scientist – bound to the normative structure of science – is an ambiguity that is built into the role of visible scientists.

Rödder (2012) explains that scientists' ambivalence about public visibility is complicated by the continuous modification of the norms that govern science in response to societal and political demands. Rödder concludes that scientists' ambivalence about public visibility may be "structurally induced" (2012:165), and adds, "the contradicting expectations that are built into the role of the visible scientist" have material, social and temporal components. The material effect relates to the clashes between what the media wants (news value: a nice story that is easy to report on and which will get the public's attention) and the criteria for quality in science (reliable and substantive new knowledge). The vastly different time frames of knowledge production and media reporting explain the temporal aspect: scientists take a long time to produce new knowledge and may need substantial time to explain it, while the media operate on short deadlines and brief sound bites. In terms of the timing of new announcements, the scientific norm is that new knowledge must be scrutinised by a peer review before it is published, but the media may argue that the public has a right to know about important new findings as they are made. Socially, conflicts arise between scientific and media recognition when scientists become media stars.

Given these conflicting views about public visibility, it should come as no surprise that a dichotomy of thought about public visibility has developed. Some studies present evidence that scientists interact smoothly and frequently with the mass media and other external audiences (Peters *et al*., 2008b; Allgaier, Dunwoody, Brossard, Lo & Peters, 2013b; Koh *et al*., 2016), while scientists who achieve celebrity status are equated with influence, power and prestige (Bucchi, 2015; Fahy, 2015). On the other hand, there is evidence that some scientists express a "striking unease *as* and *towards* visible scientists" and consistently criticise scientists who achieve celebrity status (Rödder, 2012:173). It should be noted that scientists may also achieve public visibility outside the media, for example via their participation in public events and by their social media activity.

The conflict between increasing expectations to engage with public audiences and lingering reservations about the potential consequences of doing so, fuel scientists' ambivalence about public visibility (Casini & Nerisini, 2012; Rödder. 2012). Consequently, scientists' attitudes towards making research accessible to broad public audiences are characterised by contradictions and tensions. As a result, public communication of science is described as a "professional anomaly", increasingly viewed as valuable and individually rewarding, while at the same time feared as potentially harmful (Burchell, Franklin & Holden, 2009:61).

1.10.3. Visible scientists through the ages

Since the emergence of modern science in the 17th century, every generation has yielded publicly visible scientists, although the "relative invisibility" of science and scientists became a major concern as science became professionalised and expanded in the 20th century (Bucchi & Trench, 2014:7). Fahy and Lewenstein (2015) argue that, more recently, the growth in the societal presence of science has been accompanied by a growth in the presence of scientists in popular culture. Therefore, more scientists are becoming publicly visible.

Throughout the 19th and 20th centuries, big names in science were influential in shaping societal discourse about science. Alexander von Humboldt was extraordinarily popular in Germany from about 1828 to 1845 (Bayertz, 1985). Darwin rose to fame in Victorian society after the publication of *On the origin of species* in 1859 (Shortland & Gregory, 1992). Einstein, arguably the most iconic scientist ever, became a celebrity in the period 1919 to 1921, largely due to the American press (Missner, 1985). Later in the 20th century, people such as Richard Feynman, Stephen Jay Gould, Carl Sagan and Jane Goodall became household names, while present-day popularisers, such as Richard Dawkins, Stephen Hawking, Neil deGrasse Tyson, Brian Greene, Michio Kaku and David Attenborough, continue to enjoy celebrity status (Shermer, 2002; Fahy, 2015).

Fahy (2015:204) contends that the celebrity scientists of today are the new scientific elite. Celebrity status gives these scientists "a face, force, and an impact in public life" allowing them to spread their ideas, influence policymakers, defend science and promote a culture of science in society (Fahy. However, the unusual power of celebrity also raises concerns that the status enjoyed by these scientists may outstrip their technical expertise (Fahy & Lewenstein, 2014).

Throughout the 20th century, South Africa delivered celebrated academics who were highly regarded within science, but they arguably never became household names. Names that come to mind include the visionary veterinary researcher Sir Arnold Theiler (Bigalke, 2009) and the eminent and much-loved paleoanthropologist Phillip Tobias (White, 2012; Wood, 2012). Furthermore, four Nobel science laureates were born and raised in South Africa, but continued their careers abroad, namely Sydney Brenner,[12] Aaron Klug,[13] Max Theiler[14] and Alan M Cormack.[15] Brenner won the Nobel Prize for his molecular research and discovery of programmed cell death, Klug for his macromolecular research, Theiler for his work on yellow fever and vaccine development, and Cormack for the development of computer-assisted tomography.

Perhaps the only South African scientist that has ever achieved the level of visibility that can be equated with international celebrity status was Christiaan Barnard (1922–2001) who shot to global fame after he performed the first human-to-human heart transplant in Cape Town on 3 December 1967. Barnard's article describing the surgery was published within three weeks of the event (Barnard, 1967) and became one of the most cited articles in the field of cardiovascular medicine (Brink & Hassoulas, 2009). The dramatic nature of this medical milestone and the subsequent events captured the attention of the world and was front-page news for some time. Nathoo (2009) describes this as the world's most famous operation that was as much a media focus as a medical highlight. Brink and Hassoulas (2009:31–34) suggest that Barnard's "youthful good looks and charismatic personality" contributed to the ongoing media attention. They add that the politicians at the time –

> […] undoubtedly exploited him in the years following the first transplant, in order to improve the image of South Africa at a time when repression was at its fiercest within the country and the worldwide condemnation of the apartheid regime was on the increase.

Similarly, Hoffenberg (2001:1479) describes the historic heart transplant as a "godsend" for the politicians at the time, because "things couldn't be too bad in a country that produced such an outstanding first in medicine". Barnard went on to perform several more successful heart transplants, but he was also masterful with the mass media (Nathoo, 2009) and remained an iconic public figure with a celebrity lifestyle until his death in 2001 (Logan, 2003).

[12] http://www.nobelprize.org/nobel_prizes/medicine/laureates/2002/brenner-facts.html

[13] http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1982/klug-facts.html

[14] http://www.nobelprize.org/nobel_prizes/medicine/laureates/1951/theiler-facts.html

[15] http://www.nobelprize.org/nobel_prizes/medicine/laureates/1979/cormack-facts.html

1.11. A reflection on science and society over time

There was a time when science and technology occupied a realm of genius and wizardry, a world apart that the public viewed with awe and admiration.
(Hackett, 2008:429)

1.11.1. Science and society: A tumultuous history[16]

The roots of science as a public activity can be traced back to ancient times. Science became an organised part of public life in Western society around the middle of the 17th century with the formation of the first scientific societies. These societies organised public gatherings where people could talk about their understanding of the natural world. Before that, scientific knowledge was largely esoteric and its custodians were "amateurs, alchemists, hermits and magicians" who mostly worked in seclusion (Gregory, 2009:4). In the new public ideology of science, knowledge was only deemed to be valid if its production was witnessed. So, laboratories became public spaces where scientists demonstrated and talked about their research as it was done. In the early years of scientific experimentations, some philosophers supported experiments, that could be witnessed by the public, as the way to yield new facts and produce new knowledge, while others deemed experiments to be artificial and unreliable (Schaffer & Shapin, 1985). Over time, a distinctive culture of science took shape, characterised by fierce competition for credibility and regulated by practices such as peer review (Ziman, 2000).

Commenting on the history of science communication, Gregory (2016) points out that attempts by the science community to control the public communication of science have always failed, suggesting that popularisation has independent autonomy and momentum. The author adds (2016:2):

> These centuries of history give the public communication of natural knowledge, be it mathematics, astronomy, botany, medicine or mechanics, a secure niche in the cultural life of Europe. It is not a by-product of the specialisation of scientists, but the social foundation upon which the specialists found their feet.

In the 18th century, the institutionalisation of science extended the professional distance between scientists and society, which spurred on the need to familiarise people with advances in science (Bayertz, 1985). The relationship between science and society became increasingly problematic as science became more specialised, resulting in a growing detachment between science and everyday life – a trend that continues to inform and drive public science communication today.

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[16] This brief overview focuses on the Western world, but it is important to note that the development of science, along with the communication of scientific ideas, followed a different path and timeline in colonial settings. For example, Massarani and De Castro Moreira (2016) describe how science was suppressed in Brazil during the Portuguese occupation from the 16th to the 18th century, with only the colonial powers having access to scientific knowledge thanks to their education and links with Europe. The science needs of the rulers were limited to immediate interests in fields such as navigation, astronomy, cartography, mining, plantations and the use of local plants. During British colonial rule in South Africa (1795–1910), scientific endeavours focused on the collection of plant and animal specimens for collections in London, while the science system of the country continued to serve mostly its white population during the racially segregated apartheid regime (1948–1994), thereby continuing to isolate the majority of citizens from science and suppressing science communication (Dubow, 2006).

Further signals of the growing recognition of the importance of public science communication can be traced back to the Age of Enlightenment in 18th century Europe, which spilled over to early 19th century North America (Gregory & Miller, 1998; Kyvik, 2005; Gregory, 2015). Said recognition of science communication rests on the view that, in order to develop economically, socially and culturally, society had to be informed about scientific developments. Scientists became actively involved as popularisers of research, but also used public communication to assert their authority (Gregory, 2015).

Popularisation reached its heyday in the 19th century, when it became an important part of people's self-image to keep up with advances in the natural sciences, which was considered to be the driver of social progress at the time (Bayertz, 1985:209–210); Bayertz notes that the science community intentionally sought to "awaken the spirit of science" in the public at large. Scientists competed for public attention, and Victorian science was shaped by lively interactions at scientific lectures and exhibitions (Bowler, 2009).

American newspapers of the mid-19th century took science seriously, often printing texts of popular science lectures. For example, in 1872, a special edition of *The New York Tribune* contained the physics lectures of John Tyndall and sold 50 000 copies (Shortland & Gregory, 1992). The authors recount that one of the first big science stories to feature in the popular press in Europe was the discovery of X-rays in 1896. It made the Bavarian scientist Wilhelm Röntgen famous overnight but, reportedly he was annoyed by the nature of the attention which focused on the superficial aspects of his work (the X-ray photographs) instead of the physics that made this discovery possible.

The use of the mass media to seek and sustain public support for scientific endeavours is nothing new. As long ago as 1847, Joseph Henry, the first director of the Smithsonian Institution, wrote about the need to make science publicly visible via the press (Krieghbaum, 1941). Similarly, 19th-century scientists appreciated the importance of involving the public in order to get society to recognise the value of science and increase public funding for science. Bayertz (1985), for example, relates how German scientists such as Justus von Liebig, Emile Du Bois-Reymond, Matthias J Schleiden and Ludwig Büchner, spent considerable time and energy on popularising science, clearly with material and political motives in mind.

Contrasting with the view that newspapers paid serious attention to science in the late 19th and early 20th century, as expressed by Shortland and Gregory (1992), Krieghbaum (1941) contends that media coverage of science before the First World War (WWI) was tardy and inadequate, adding that even a milestone event such as the Wright Brothers' flight in 1903 was poorly reported. This changed in the period after WWI when specialist science editors appeared on the scene and science journalism became professionalised. According to Van Deventer (1957), one of the first science news stories that was accurately and comprehensively reported in the American press was Einstein's theory of relativity by observation of a total solar eclipse in 1919. With the advent of better media coverage of science, the public now also had more access to information about the implications of science for society than before.

Nelkin (1995) explains that, as a result of an expanding scientific enterprise between the two world wars, science increasingly needed public support, prompting scientists to look for ways to enhance their public image. According to Goodell (1975:67), science in the era before the Second World War (WWII) was still predominantly regarded as a scholarly pursuit with little political interference, but also not particularly well funded. "Receiving little from society, science also gave little: it did the research, and left the consequences up to society" (Goodell, 1975:67).

In the aftermath of WWII,[17] the achievements of science were credited as aiding America to win the war, and people were grateful for the role of science in helping the Allied forces to maintain the integrity of the free world (Morison, 1969; Hartz & Chappell, 1997). Media coverage during and after WWII celebrated the achievements of science in encouraging and morale-boosting terms (Shortland & Gregory, 1992). In the post-war years, progress towards the so-called 'endless frontier[18] of science' was seen as the means by which nations would ensure and sustain health, prosperity and security for their citizens[19] (Bush, 1945). In return, the public was expected to sanction research funding and endorse scientists' licence to practise (House of Lords, 2000). The social prestige enjoyed by science translated into interest from the press, and scientists increased their public communication efforts (Morison, 1969; Doubleday, 2009).

Since the atomic bomb and subsequent technological developments, science was no longer only associated with victory and progress, but also with danger, devastation and environmental ruin (Goodell, 1975). People became increasingly uneasy about the alliance between science and the military, the cost of scientific progress in terms of the exhaustion of natural resources, and the ethical questions that began to characterise advances in biology (Morison, 1969). The realisation that the ability of science to control the material world did not necessarily mean that science would be used for the benefit of mankind, was dawning steadily and uncomfortably. Scientists were faced with a moral sense of responsibility for the consequences of their discoveries, as well as an obligation to report to the public. These changes put pressure on science "to update its antiquated concepts of how much to tell society, when, and how" (Goodell, 1975:9).

When the Soviet Union launched their Sputnik satellite in 1957, America responded with vigorous attempts to improve public awareness and knowledge of science (McGowan, 1985) and infused funds into pre-college science education (Laetsch, 1987). However, Nisbet and Scheufele (2009)

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[17] Wars (whether global or regional conflicts, or even the so-called Cold War of the mid-20th century) have always shaped science and the way it is communicated. Typically, secrecy is demanded of scientists working on strategic projects during war time (Cribb & Hartomo, 2002) and it may even be a criminal offence for scientists to talk publicly about their work during wartime (Hartz & Chappell, 1997).

[18] '*Science – the endless frontier*' was the title of a post-war report on scientific research, presented to the US President in July 1945. It was written by Vannevar Bush in his capacity as director of the Office for Scientific Research and Development.

[19] Vannevar Bush used the metaphor of science as "the goose laying golden eggs" to capture the role of science in ensuring societal prosperity and delivering economic growth, social progress and military advances (Bucchi & Trench, 2014:3).

argue that it is a myth that this introduced a golden age of scientific literacy, since surveys of the American public continued to show low levels of interest in and knowledge about science.

In the 1960s, the argument that citizens needed to have an understanding of how science operates continued to provide a rationale for promoting public understanding of science, mainly motivated by the idea that many issues that citizens had to deal with, such as environmental problems and the population explosion, required scientific knowledge (Lewenstein, 1992a). Despite a lack of evidence that the public actually wanted to know, scientific leaders were morally certain that popularising science was important. Lewenstein (1992c:59) points out that this science advocacy was in all likelihood motivated by "simple and fundamental patriotism" and a genuine concern that the United States should not fall behind in science. The author points out, however, that advocates for public understanding of science, were in fact promoting public appreciation of (and support for) science and its benefits. This issue would only become more pronounced as anti-science sentiments began to surface along with the early environmental and anti-nuclear movements of the 1960s.

The publication of *Silent Spring*[20] (Carson, 1962) drew public attention to a simmering ecological crisis in post-war America and further strained the science–society relationship (Bensaude-Vincent, 2014). As opinion leaders started blaming science for societal ills such as pollution, environmental deterioration and escalating inequality, scientists increasingly gained the impression that the public had lost confidence in science and that they could no longer count on public goodwill (Goodell, 1975).

1.11.2. Eroding trust and a crisis of public confidence

A new era dawned for science in the late 1960s when public disenchantment with science started to affect scientific freedom and funding, resulting in restrictions and budget cuts (particularly in the United States). At the same time, scientists became more specialised and the knowledge they produced more obscure, leading the public to perceive scientists as working in an 'ivory tower' where they communicated only with one another, with little concern for society (Goodell, 1975).

Around this time (mid-20th century), renewed calls for scientists to engage with public audiences started to emerge. For example, despite his belief that the general population had a limited capacity to understand and appreciate science, Morison suggested that the science community should renew its efforts to educate the public via the school system and the press in an effort to counter public indifference and hostility towards science, by saying (Morison, 1969:154):

> I still believe that much more can be done to improve matters than has been done so far. Science can no longer be content to present itself as an activity independent of the rest of society, governed by its own rules and directed by the inner dynamics of its own processes. Too many of these processes have effects which, though beneficial in many respects, often strike the average man as a

[20] *Silent Spring,* written by Rachel Carson and published in 1962, denounced the devastating effects of the widespread use of pesticides, and is credited as a foundation of the environmental movement in the United States, and one of the reasons for the formation of the Environmental Protection Agency in 1972 (Bensaude-Vincent, 2014).

> threat to his individual autonomy. Too often science seems to be thrusting society as a whole in directions which it does not fully understand and which it has certainly not chosen.

From the 1980s onwards, the moral and ethical questions surrounding emerging technologies intensified societal debate about the acceptability and desirability of cutting-edge science, while divided opinion about issues rooted in science further polarised societies around the globe (Hornig Priest, 1994; Scheufele & Lewenstein, 2005; Gupta, Fischer & Frewer, 2012). Knowledge production was moving into an era of increased sensitivity about the broader societal implications of scientific advances. At the same time, there was a growing realisation of the need to involve the public, even as new knowledge was produced. These changes implied that scientists had to start moving into public spaces to engage pro-actively with the public and the mass media (Gibbons, 1999).

In the late 1990s, Jane Lubchenco, AAAS president at the time, urged scientists to change their ways by considering a new social contract with society in response to "urgent and unprecedented environmental and social changes as they entered the century of the environment" (Lubchenco, 1998:491). She appealed to scientists to step up their efforts to communicate new knowledge effectively to public and policy audiences. Hartz and Chappell (1997:xii) claim that eroding public support "jolted" scientists from their complacency about funding that used to come "without question".

Towards the end of the 20th century, several high-profile crises and controversies heightened societal uncertainty about science, bolstered anti-science sentiments and strained science–media relationships. Notable examples include the accident at Three Mile Island in 1979 (Stephens & Edison, 1982), the 1986 Chernobyl disaster (Peters, 1992), the cold fusion saga from 1989 onwards (Lewenstein, 1992b; Simon, 2001), the 1992 polemic around the MMR[21] vaccine (Flaherty, 2011; Rao & Andrade, 2011), and the BSE[22] scare during 1996 (Jasanoff, 1997; Pitrelli, 2003; Irwin, 2009). These national and regional controversies and disasters often cast long shadows and spread around the world. For example, the UK debate around vaccines spread quickly to other countries, and its ramifications continue to fuel anti-vaccination lobbies around the globe (Horne, Powell, Hummel & Holyoak, 2015).

The 21st century has not been spared from disasters that further influenced public opinion about science. For example, the 2011 Fukushima disaster not only made the Japanese public more critical of nuclear installations, but also affected public opinion about nuclear energy elsewhere (Sugiman, 2014; Li, Akin, Su, Brossard, Xenos & Scheufele, 2016). Just six months after deciding to expand nuclear energy, the Fukushima disaster caused the German parliament to decide in favour of phasing out nuclear energy completely (Arlt & Wolling, 2016). Environmental events, such as the

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[21] The MMR vaccine is an immunisation vaccine against measles, mumps, and rubella.

[22] BSE is an abbreviation for 'bovine spongiform encephalopathy'. This disease (commonly known as 'mad cow disease') is a fatal neuro-degenerative condition.

1989 Exxon Valdez disaster and the 2010 BP Deepwater Horizon oil spill (Sylves & Comfort, 2012) further highlighted the catastrophic potential of complex technical energy systems.

These stresses and strains between science and society reverberated throughout the Western world, and public communication of science was identified as a way to calm down tensions (Leshner, 2006) and restore scientific credibility and authority (Gieryn, 1995). Consequently, policymakers persistently implored scientists to engage with society in order to counter anti-science sentiments (Bodmer, 1985; Cicerone, 2006; Reddy, 2009). This implied a belief that science funding would be politically vulnerable if scientists declined to debate their work with society and a conviction that public opinion would ultimately be able to exert influence over science policy (Miller, 2001).

Towards the end of the 20th century, the scientific establishment was troubled by the perception that some scientists preferred to retreat from the public stage because they were either unwilling or unable to communicate with the public. Following the publication of an influential report by The Royal Society in 1985 calling for greater public participation in science and the validation of science as a public good (Bodmer, 1985), the 'public understanding of science' movement emerged in the United Kingdom (Watermeyer, 2011).

Moving on from seeing the public as an undifferentiated, passive and compliant mass, a trend towards dialogue and engagement, characterised by a more equitable relationship between scientists and their publics, emerged (Irwin, 2001; Wilsdon & Willis, 2004; Holliman & Jensen, 2009). New public engagement formats designed to promote two-way discussion between experts and lay people became fashionable in Europe, such as citizen juries, consensus conferences and science cafés (Felt & Wynne, 2007). Public communication of science became a key agenda item for policymakers in the European Union (EU), leading them to urge, and even oblige, European scientists to reflect on the social context of their work and listen to societal concerns about science (Claessens, 2008), as reflected in this policy report (EURAB, 2007, cited in Claessens, 2008:36):

> Researchers should remain aware of how the actions of the past have generated negative public perceptions of research today … and that better dialogue with the public either directly or via the societal actors could have prevented much of the friction and lost potential of innovative developments in these research fields.

Throughout this period, several drivers continued to fuel the perception of an ever-widening gulf between science and society, while rapid advances in science spurred on the perceived need to bridge this distance (Bultitude, Rodari & Weitkamp, 2012; Scheufele, 2013; Von Winterfeldt, 2013). Some social scientists, however, started to question the existence and nature of the perceived gap between science and the public. For example, Lévy-Leblond (1992) points out that all people, scientists and non-scientists alike, share a common ignorance about some aspects of highly specialised science. He concludes that, instead of a single gap between science and society, there are multiple gaps between specialists and non-specialists in each field of science. Bensaude-Vincent (2009) questions whether science popularisers, who position themselves as mediators between science and society, are deliberately reinforcing this perceived gap in order to legitimise their own roles. The author proposes a more contemporary view of a process of alienation between science and society as the inevitable result of the advancement of science and a key ingredient of the nature of science itself.

As emerging technologies continued to present more complex ethical challenges, leading to a more critical and polarised public, the erosion of public trust in science became an ever-increasing concern for the scientific establishment (Wilkie, 1996; Haerlin & Parr, 1999; Wynne, 2006; Bultitude, 2011; Gauchat, 2011; Resnik, 2011; Scheufele, 2013; Kraft, Lodge & Taber, 2015; Nisbet & Markowitz, 2015a). Social science scholars reflected with unease on the demise of the authority and credibility of science (Nowotny, 1981; Wynne, 1992; Weingart, 2002). Scientists were concerned about their dwindling status, declining public support and even outright hostility towards science (House of Lords, 2000), but they were also anxious about trying to fix this through public engagement. These attitudes are pithily summarised by Greenwood[23] (1996:933) in a *Science* editorial with the title 'Desperately seeking friends':

> This is a tough time to many scientists. The money is getting increasingly tighter, and the nation as a whole shows alarming anti-intellectualism … Furthermore, the demand for efficiency and accountability in the use of public funds is constantly increasing. It is not hard to understand scientists' growing sense of apprehension and uncertainty. It's time for us to make new friends. But do we know how? We want people to like us, support us, and understand how dedicated we are. However, we don't want to be told that it is our responsibility to be more civically inclined … We're busy, we claim. Can't someone else do the public outreach?

Around the turn of the 20th/21st century, public science communication remained high on the science policy agenda, and was at the time driven by the perceived need to restore public trust and support. A series of high-level policy documents accentuated the importance of public engagement and legitimised spending on public communication (Wolfendale Committee, 1995; DACST, 1996, National Science Board, 1998; 2000; House of Lords, 2000). Concerned leaders in the scientific world called for a new relationship between science and society where science would be more transparent, socially responsive and better connected with diverse audiences (Lubchenco, 1998; Demeritt, 2000; Gallopín, Funtowicz, O'Connor & Ravetz, 2001; Hessels & Van Lente, 2008). Instead of the one-sided promotion of science, scholars in the field of science communication advocated for open and frank dialogue between science and society, including debate about the limitations and implications of science (Borchelt, 2001; Miller, 2001).

Globally, a new mood for dialogue between science and society, first mentioned in the UK House of Lords Report (2000), started to take hold. As emphasised in this UK policy report, scientists were encouraged to normalise discussion with society and openly acknowledge uncertainty in science. The emerging consensus was that science should earn its authority by giving citizens a voice (Wakeford, 2010) and by encouraging public input into science (MORI, 2001; Van der Sanden &

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[23] At the time of writing this editorial, MRC Greenwood was the dean of graduate studies and vice provost at the University of California, Davis, and former associate director of science at the Office of Science and Technology Policy. She became chancellor at the University of California, Santa Cruz, on 1 July 1996.

Meijman, 2008; Davies, 2011). Science communicators started to experiment with new participatory engagement approaches, and deliberative models in the public–science debate and science policy formulation (Nisbet & Scheufele, 2009; Dietz, 2013; Burgess, 2014) as well as the co-production of knowledge between science and lay persons (Bäckstrand, 2003; Palmer & Schibeci, 2012; Jucan & Jucan, 2014).

Today, the production and communication of new scientific knowledge are subject to socio-political pressures and trends. Science has moved away from a closed system where scientists worked largely in isolation and enjoyed public trust, to a more transparent system where research has become more publicly visible and science is subject to public scrutiny (Wilsdon & Willis, 2004; Porter, Williams, Wainwright & Cribb, 2012). In the closed system, communication with the public was characterised by a one-way, top-down flow of information, while the current trend is towards dialogue between science and society and transparent debate about contested topics rooted in science (Trench, 2008; Brossard & Lewenstein, 2010; Stocklmayer, 2013). As noted by Stilgoe and Wilsdon (2009:18), “the monologue has become a conversation”.

Furthermore, the inherently political nature of science is increasingly accepted (Hackett, 2008), bringing about a realisation of the need to justify public spending on research and to pay attention to the societal implications of science. Consequently, not only science itself, but also its communication, has become deeply politicised (Scheufele, 2014; Gregory, 2015; Nisbet & Markowitz, 2015b).

The notion that publicly funded scientists share a responsibility for public science communication has become widely accepted by research funders, science managers and scientists alike (Dickson, 2010; Corley *et al.*, 2011; Grand *et al.*, 2016). It is even regarded as scientists’ moral duty, particularly for researchers who work on topics that have moral or ethical implications (European Commission, 2007; Torres-Albero *et al.*, 2011; Marcinkowski *et al.*, 2014). Accordingly, public communication of science is progressively recognised as a legitimate activity for research organisations, and scientists are consistently called on to give public lectures, speak to the press and take part in consensus-building exercises with the public (Bauer *et al.*, 2007; Bauer & Jensen, 2011).

Within research institutions, activities such as community engagement and public service are gaining acceptance as legitimate third-stream activities alongside teaching and research (Jacobson *et al.*, 2004; Andrews *et al.*, 2005; Bond & Paterson, 2005), The concept ‘an engaged university’ has become firmly entrenched on the tertiary landscape (Whitmer *et al*., 2010; Grand *et al*., 2015). Major research funders, such as the National Science Foundation (NSF) (Kamenetzky, 2013; Wiley, 2014) and Higher Education Funding Councils (Chikoore *et al.*, 2016; Terama, Smallman, Lock & Johnson & Austwick, 2016) have introduced societal impacts as one of the criteria they consider when scientists apply for and report on research funding.

1.11.3. New media and changing politics

In digital environments, the information consumer has considerable control and is able to select information that confirms existing opinions, while avoiding conflicting views. The algorithms behind social media platforms and search engines exacerbate the formation of so-called 'echo chambers' or 'filter bubbles', resulting in cognitive mechanisms known as 'motivated reasoning' and 'cognitive bias' (Knobloch-Westerwick, Johnson, Silver & Westerwick, 2015; Yeo, Xenos, Brossard & Scheufele, 2015). The net effect of these changing patterns in the way people access and use information, is that people tend to become more polarised about many issues, including science. Furthermore, the sophisticated tracking of people's interests makes it possible for online content providers to target people, based precisely on their information-seeking and consumption patterns. This means that the traditional concept of broadcasting (radio and television) is replaced by narrowcasting (in online environments), thereby widening the rifts between different ideological groups and herding like-minded people into insular social tribes (Scheufele, 2016).

This problematic communication scenario is further aggravated by rising anti-intellectual sentiments in many parts of the world (Butler-Adam, 2017) and phenomena that go against the grain of science, such as 'fake news', 'alternative facts' and 'post-truths'[24] where scientific evidence may be ignored or relegated to a matter of opinion (Higgins, 2016). This presents new communication challenges to scientists who wish to restore public trust in science and promote evidence-based arguments (Gewin, 2017). Once again, scientists are called upon to fight post-factual positions and to retaliate against the inaccuracies and misinformation in online environments (Campbell, 2017). According to Butler-Adam (2017:1):

> Facing – and facing down – positions grounded on emotion-based fallacies is not an easy stance to assume, and will, in all likelihood, become more difficult in an increasingly populist world. Yet it is a duty that universities and their scientists cannot afford to neglect.

Williamson (2016:171) presents a compelling argument for scientists who doubt whether it is worth the effort to try and combat misinformation:

> Challenging falsehoods and misrepresentation may not seem to have any immediate effect, but someone, somewhere, will hear or read our response. The target is not the peddler of nonsense, but those readers who have an open mind on scientific problems. *A lie may be able to travel around the world before the truth has its shoes on, but an unchallenged untruth will never stop.*

It is important to note that recent insights from social psychology and related disciplines show that providing counter-arguments to try and fix misunderstandings is a strategy likely to fail (Requarth, 2017; Zimmerman, 2017). Instead, scientists are urged to get to grips with the science behind effective communication of science, which shows that personal relevance and emotional resonance may be more effective strategies for nurturing public trust in science (Myers, Nisbet, Maibach & Leiserowitz, 2012; Fischhoff & Scheufele, 2013). For example, an analysis by McKinnon and Orthia

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[24] The Oxford Dictionaries named 'post-truth' as their 2016 'Word of the Year' (Higgins, 2016). Post-truths are lies that become widely accepted as truths with a vast majority of people who not only accept it as the truth, but also continue to propagate it (Butler-Adam, 2017).

(2017) shows that, as far as addressing vaccine hesitancy is concerned, communication strategies that comprise personal stories and emotional appeals may be more effective than relying primarily on scientific fact to convince parents.

1.11.4. Ongoing public science communication challenges

The perception that scientists must carry some of the blame for the erosion of their relationship with society and the persistence of low public scientific literacy fuels the rationale that remedial interventions are needed (Bensaude-Vincent, 2001; Dunwoody *et al*., 2009). Consequently, science and policy leaders regularly remind scientists of their responsibility to reach out to society, operate in closer proximity to fellow citizens and protect science against hostile smear campaigns (Leshner, 2003; Mooney & Kirshenbaum, 2009; Searle, 2011). Acknowledging that this demand on scientists is not new, Dunwoody, Brossard and Dudo (2009:299) suggest, “the prestige behind today's signals suggests that the scientific culture is giving renewed and growing attention to scientists' role in popular science communication”.

At the same time, the current global economic austerity is putting pressure on science resources, with the result that research organisations have a vested interest in attracting favourable public attention. Under these conditions, institutional motives for prioritising public communication of science may be aligned with self-serving agendas, rather than an aspiration for dialogue with society (Kohring, Marcinkowski, Lindner & Karis, 2013; Weingart & Guenther, 2016). Furthermore, Weingart (2005, cited in Liang *et al*., 2014) points out that the desire for public acceptance of science, especially when it comes to emerging technologies with significant social and ethical implications, inspires a discourse of legitimation of science in the mass media. Consequently, scientific institutions, as well as some scientists, increasingly orient themselves toward the media (Weingart, 2012) and mass media become more attentive towards science (Rödder, 2009).

Despite the ongoing challenges at the science–society interface, scholars point out that, in recent decades, science and society have become more closely linked. Science and society are also characterised by dynamic interactions and permeable boundaries (Bucchi & Trench, 2014).

Globally, the science community is investing in tools, incentives and training programmes designed to improve scientists’ communication skills and facilitate their public engagement efforts (Leshner, 2007; Trench & Miller, 2012). Science engagement platforms that have become popular in many countries (including on the African continent) include science festivals (Winter, 2004; Martín-Sempere, Garzon-Garcia & Rey-Rocha, 2008; Durant & Ibrahim, 2011), science cafés (Clery, 2003) and public platforms for young scientists, such as FameLab (Trench *et al.*, 2014). It has become commonplace for scientists who are actively involved in public communication themselves to offer advice to their peers on the pages of scientific publications (Baum, 2006; Condit, 2007; Baron, 2010a; Darling, Shiffman, Côté & Drew, 2013; Varner, 2014; Cooke, Gallagher, Sopinka, Nguyen & Skubel, 2017), and to write popular books, aimed at fellow scientists, about science communication skills (Shortland & Gregory, 1992; Dean, 2009; Baron, 2010a; Olson, 2009; 2013; 2015).

Weingart and Guenther (2016) propose three core reasons for the explosive growth in the popularity of public science communication, namely the rise of science PR, the drive to make science more democratic, and the need to legitimise science funding. Jointly, these factors put growing pressure on scientists to engage with public audiences. Furthermore, the globalisation of science and the rise of big, multinational science projects are forcing scientists to explore new communication strategies that will get the attention of large science funders (Whitley, 1985; Polino & Castelfranchi, 2012), while the recent emphasis on responsible research and innovation (RRI) also calls for communication outside the academic environment (Felt & Fochler, 2012).

Governments are major drivers of the global proliferation and institutionalisation of public science communication. There are numerous examples of government-driven policy directives and initiatives designed to promote interaction between scientists and society (Trench *et al.*, 2014). For example, a 1993 white paper, 'Realising our Potential', commits the UK government to promoting public understanding of science, and mandates research councils to fund-related activities (Wolfendale Committee, 1995; Pearson, 2001). Similarly, a South African white paper on science and technology (DACST, 1996) calls on scientists to engage with society, especially rural communities and women.

These days, research funders also demand broad dissemination of research outputs and evidence of public engagement, and scientists have to present public communication strategies as part of their grant applications (Pearson, 2001). Since 1997, the NSF[25] evaluates grant proposals not only on intellectual merit, but also on its so-called 'broader impacts', which is a criterion introduced to narrow the gap between science and society (Nadkarni & Stasch, 2013; Wiley, 2014; Skrip, 2015; Watts, George & Levey, 2015). In 2014, the Higher Education Funding Councils in the United Kingdom introduced a Research Excellence Framework that, for the first time, included research impact as one of its funding criteria that would account for 20% of the allocated funds (Terama *et al*., 2014). Similarly, the UK Department for International Development (DFID), a major donor for research in developing countries, stipulates that 10% of their research funding must be allocated to communication and knowledge-sharing activities to ensure societal uptake of the research (Bakyawa *et al.*, 2013; DfID - Department for International Development, 2016). Likewise, the European Commission accentuates public communication as a criterion for research funding (European Commission, 2017a). For example, Article 38 of the model grant agreement in its Horizon 2020 Programme, reads as follows (European Commission, 2017b:81): The beneficiaries must promote the action and its results, by providing targeted information to multiple audiences (including the media and the public), in a strategic and effective manner.

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[25] Major funding agencies, including the NSF, have adopted public understanding of science as a strategic objective. For example, the NSF Strategic Plan 2014–2018 (NSF, 2014:9) says:

> [the] NSF has the opportunity and responsibility to leverage our research and education activities to engage the public and help citizens develop a better understanding of science, one that can inform opinions about issues faced in daily living, in participation in the democratic process, and in helping to advance science.

In order to satisfy the requirements of policymakers and research funders, scholars are working on indicators to measure and monitor public communication activities (Nisbet & Mooney, 2007; Roberts, 2009; Vetenskap & Allmänhet, 2011; Palmer & Schibeci, 2012).

For their part, research organisations, including prestigious universities and global scientific societies are investing in training and incentives to encourage and support scientists' public engagement work and embed a culture of public engagement in higher education (Poliakoff & Webb, 2007; Dunwoody *et al*., 2009; Miller & Fahy, 2010; Burchell, 2015). Consequently, courses and platforms designed with public science communication in mind, are thriving (Brown *et al*., 2004; Reddy, 2009; Miller & Fahy, 2010; Smith *et al*., 2013; Whitmer *et al*., 2010).

Notable examples are the Aldo Leopold Leadership Programme at Stanford University (Gold, 2001; Whitmer *et al*., 2010) and the Center for Public Engagement with Science at the AAAS (AAAS, 2016).

Organisations that promise to build bridges between scientists and journalists have attracted considerable interest and investment, such as Science Media Centres in the UK and Australia (Fox, 2012; Callaway, 2013), as well as science press release aggregators such as EurekAlert! (Pinholster & Malley, 2006) and AlphaGalileo (Green, 2006; Trench, 2009). While mainstream engagement platforms, such as mass media and public lectures, remain important, scholars note an increase in novel and creative approaches to science communication, including storytelling, humour and artistic expression (Dahlstrom, 2014; Kaiser, Durant, Levenson, Wiehe & Linett, 2014).

Historically, the Anglo-Saxon world has played a leading role in public science communication, both in practice and research (Bauer & Howard, 2013), but the field is expanding rapidly in other countries. Trench *et al*. (2014) reflect on emerging activities in Argentina, Estonia, Malaysia, Nigeria and Turkey, noting striking parallels and similar commitments in these diverse settings. Scholars have also drawn attention to the roots and evolution of science communication in populous regions of the world, including Latin America, Africa, India and China (Joubert, 2001; Manzini, 2003; Mazzonetto, 2005; Du Plessis, 2008; Jia & Liu, 2014; Massarani, 2015; Massarani & De Castro Moreira, 2016).

Chapter 2: Theoretical perspectives and conceptual framework

> ***Human action, being socially situated, is the product of a dynamic interplay of personal and situational influences … to make their way successfully through a complex world, people have to make sound judgements about their capabilities, anticipate the probable effects of different events and actions, ascertain socio-structural opportunities and constraints, and regulate their behaviour accordingly.***
> *(Bandura, 1999:155)*

2.1. Theoretical basis

Human behaviour is complex, and therefore challenging to study and understand. The first step in understanding a specific human behaviour is to identify it and to consider the beliefs people may have about performing the behaviour in question (Fishbein & Cappella, 2006). It then becomes possible to apply a theoretical model to understand why some members of a specific group are performing the behaviour, while others are not. This study focused on a specific type of behaviour, namely 'public science communication behaviour' as performed by scientists themselves.

Human behaviour is influenced by attitudes, intentions, norms and abilities, and all of these are guided by individual beliefs (Ajzen, 1985; Fishbein & Cappella, 2006). Some of the incentives and barriers regarding public science communication occur at the level of the individual (such as age, gender, personality type), while other influences manifest at the institutional level (such as organisational culture) or the systemic level (scientific norms). Consequently, it is necessary to draw on behavioural theories that consider individual behaviour (typically rooted in social psychology), as well as theories relevant to scientists' social contexts (typically based in sociology).

The current study appropriated concepts from two major behavioural theories, namely the theory of planned behaviour (Ajzen, 1991) and social cognitive theory (Bandura, 1986). Both these theories consider individual behaviour as well as the broader social context in which the behaviour takes place. In order to make the theoretical framework specifically relevant to the public communication behaviour of scientists, the study also drew on two extensions of the theory of planned behaviour, proposed by Poliakoff and Webb (2007) and Dudo (2013). Furthermore, a sociological model for the social nature of communication, suggested by Riley and Riley (1959), was added to place public communication of science within society. Lastly, theories concerning the normative nature of science by Merton (1938; 1942; 1968; 1973) were considered because of their relevance to scientists' motivations and behaviours. Applying these theories to the research literature made it possible to isolate, group and compare the factors that influence scientists' public communication behaviour.

The current study focused on attitudes and motivation as two key determinants of human behaviour, and explored a range of factors that would (or could) influence attitudes and motivation.

Attitudes reflect an individual's enduring evaluation, positive or negative, of engaging in a particular behaviour (Eagly & Chaiken, 1993) and therefore feature prominently in my theoretical framework as a factor that govern and predict human behaviour. For example, the theory of planned behaviour (Fishbein & Ajzen, 2010) postulates that a positive attitude toward a particular behaviour increases the likelihood that a person will perform such behaviour. Logically then, scientists are more likely to engage in public communication if they have a favourable attitude towards doing so (Armitage & Conner, 2001). Notably, a positive attitude does not necessarily lead to participation (Van der Auweraert, 2008), and researchers' attitudes may change over time in response to policy changes, normative shifts and ideological trends. Historians of science report how, throughout history, the interaction of scientists with society have alternated between enthusiastic engagement and retreat to the ivory tower (Bourdieu, 1989; Kyvik, 2005; Bowler, 2009).

To be **motivated** "means to be moved or energised to do something", and this is also related to the underlying attitudes and objectives that explain why people do or do not perform a specific behaviour (Ryan & Deci, 2000:54). Two key types of motivation, intrinsic and extrinsic, were explored (Deci & Ryan, 1985; Ryan & Deci, 2000). **Intrinsic** motivation moves people to do something because they find it meaningful, interesting, satisfying or enjoyable. These behaviours are voluntary and emanate from an individual's sense of self. **Extrinsic** motivation drives behaviour because it is expected to lead to a specific outcome or reward. These behaviours result from external pressure and control that direct someone towards a specific behaviour.

2.2. The theory of planned behaviour

The theory of planned behaviour[26] is widely regarded as one of the best-supported and most widely used social-psychological theories with respect to human behaviour, and is well suited to study the communication behaviour of scientists, since knowledge sharing is an intentional behaviour (Fishbein & Cappella, 2006; Bousari & Hassanzadeh, 2012; Dudo & Kahlor, 2017). Dudo and Besley (2016) provide empirical validation for applying the theory of planned behaviour in the context of public communication of science by demonstrating that scientists' valuations of specific communication goals are associated with key predictors from this theory. Furthermore, Guenther (2014) applied this theory successfully to study the behaviour of science journalists.

The theory of planned behaviour postulates three independent determinants of intention, namely the attitude towards the behaviour, subjective norms, and perceived behaviour control. These determinants stem from an individual's behavioural, normative and control beliefs respectively. The term 'belief' refers to the attitude of an individual about whether something is true or not (Schwitzgebel, 2015). People may hold a great many beliefs about any given behaviour, but they can attend to only a relatively small number at any given moment. These are the salient beliefs that will determine individual intentions and actions (Ajzen, 1991). These beliefs are explained as follows by Ajzen (2005) and Sommer (2011):

[26] The theory of planned behaviour is an extension of the theory of reasoned action, one of the classic persuasion models of psychology developed by Fishbein and Ajzen in 1967, originating from research focusing on theoretical models of attitude (Ajzen, 1991).

- *Behavioural* beliefs depend on the expected consequences of a behaviour, and jointly they result in a positive or negative attitude towards that behaviour.
- *Normative* beliefs relate to the normative expectations of other people, which constitute the underlying determinants of subjective norms.
- *Control* beliefs relate to the presence of factors that may facilitate or impede behaviour, which provide the basis for perceptions of behavioural control.

Fink's (2016) list of reasons why some scientists avoid public communication about their work is a good example of how scientists' behaviours are influenced by a blend of behavioural, normative and control beliefs:

- they are interested, but genuinely just too busy or worried that it will dilute their primary research efforts;
- they fear leaking of unpublished research results;
- they are concerned that their colleagues will view their social media activity as unprofessional or a waste of time;
- they are genuinely convinced that others are better at public science communication than they themselves;
- they face institutional barriers;
- they are too shy and lack confidence;
- their communication style is too dry and/or ineffective;
- they do not have any funding for communication activities; and
- they do not have the contacts or experience to get started.

In her study of scientists in Belgium, Van der Auweraert (2008) looked for explanations for scientists' public communication behaviour in terms of willingness, permission and ability. This corresponds directly with the three determinants in the theory of planned behaviour, namely attitude, subjective norm and perceived behavioural control. The author points out that attitude, the subjective norm and perceived behavioural control may each influence a researcher's behaviour separately, but that these influences also interact, thereby enhancing or suppressing one another. For example, a positive attitude about performing a specific behaviour will not be sufficient if the researcher lacks the skills or opportunity to perform the behaviour in question. Equally, a researcher may participate in public communication about her/his work, driven by intrinsic motivations and a perception of duty, despite fears of negative feedback from colleagues.

Poliakoff and Webb (2007:245) explain the essence of the theory of planned behaviour as it applies to the communication behaviour of scientists, as follows:

> The best predictor of whether a scientist will take part in a public engagement activity is the direction (shall I/shan't I) and strength (how much do I want to/not want to) of their behavioural intention.

Ajzen (1991) points out that some behaviours meet this requirement (the stronger the intention, the more likely the behaviour) quite well. However, Ajzen notes that a strong intent is not enough to ensure that a specific behaviour will be performed. Whether someone does something or not also depends on factors that do not depend on motivation, such as opportunities and resources (e.g. time, money and skills). These factors determine people's actual control over the behaviour. Therefore, the behaviour depends jointly on motivation (intention) and ability (behavioural control). Actual control feeds back to perceived control, and performing the behaviour feeds back to the three beliefs underlying the three determinants of intention.

According to Poliakoff and Webb (2007), 'perceived behavioural control' refers to the extent to which people perceive a specific behaviour to be under their control (whether they have the required resources, skills and opportunities), as well as to its perceived level of difficulty (whether they will be able to do it). Perceived behavioural control "is assumed to reflect past experience as well as anticipated impediments and obstacles" (Ajzen, 1991:188). Therefore, own experience of a specific behaviour, as well as one's perceptions of the experiences of friends and peers, will influence the perceived difficulty of performing a specific behaviour. Ajzen (1991:196) explains, "The more resources and opportunities individuals believe they possess, and the fewer obstacles or impediments they anticipate, the greater should be their perceived control over the behaviour."

Perceived behavioural control affects behaviour directly, but also indirectly through its effect on intentions. Someone's intention to perform a specific behaviour is central to the theory of planned behaviour, as explained by Ajzen (1991:181):

> Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour.

Furthermore, perceived behaviour control links closely with the concept of self-efficacy, i.e. people's beliefs in their capability to perform a specific behaviour (Bandura, 1977). People with a resilient sense of self-efficacy in a given domain will behave differently in that realm of activity compared to those who are beset by self-doubt (Bandura, 1999). Likewise, social cognitive theory demonstrates that people are more likely to participate if they believe they will succeed at a specific behaviour (Bandura, 1986) than if they do not believe so. According to the theory of planned behaviour, self-efficacy is a dynamic belief system that varies depending on the situation and the activity in question (Ajzen, 1991). Bandura (1999) points out that people are not passively shaped by their environment, instead they are able to reflect on a situation and take action to achieve certain results.

It is important to note that not all behaviour is voluntary. For example, Trafimow, Sheeran, Conner and Finlay (2002) explain that, even if someone may strongly intend to do something, the individual may refrain from the behaviour because of a lack of ability or other external constraints. Therefore, the concept of perceived behavioural control allows the theory of planned behaviour to predict not only voluntary behaviour, but also planned and deliberate behaviour.

In a reflection on the applications of and criticisms on the theory of planned behaviour, Ajzen (2011) explains that background factors, including demographic variables such as age and gender, may also influence people's behavioural, normative and control beliefs. It is therefore reasonable to expect that these factors will also influence intentions and behaviour. The author suggests that background factors should be considered, whether for intuitive or theoretical reasons, and that these background factors should be included when a specific behaviour is examined. Ajzen (1991:199) further points out, "personal feelings of moral obligation or responsibility to perform, or refuse to perform, a certain behaviour" should also be considered, since such feelings of moral obligation would be expected to influence a person's intentions to perform the behaviour. In Figure 2.1, I illustrate the constructs of the theory of planned behaviour, such as how background factors influence beliefs, and how these beliefs lead to attitudes, subjective norms and perceived behavioural control, which, in turn, influence intention and, ultimately, behaviour.

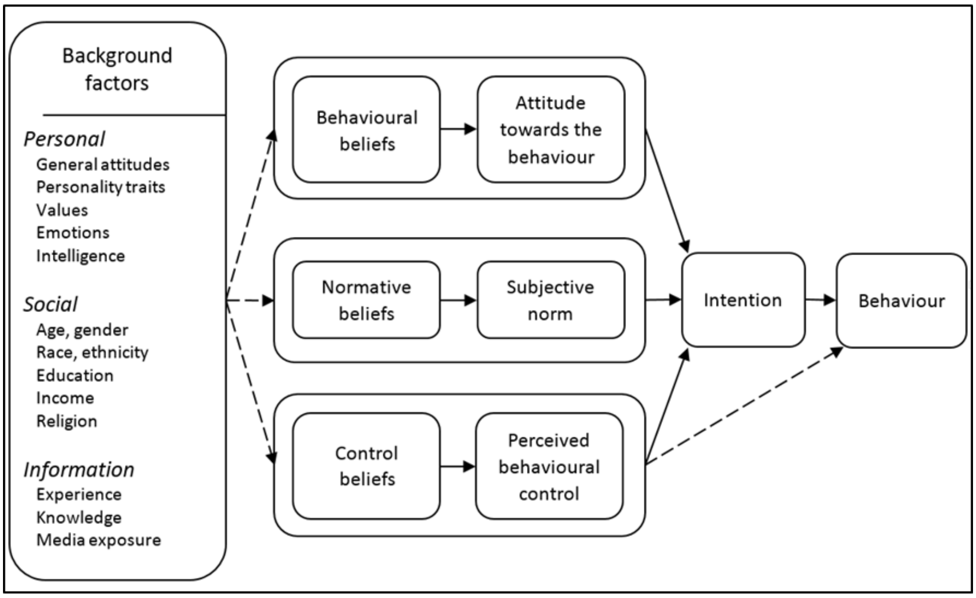

Figure 2.1: Constructs of the theory of planned behaviour
(Source: Ajzen, 2005:135)

2.3. Social cognitive theory

Social cognitive theory provides another useful lens to study public communication behaviour amongst scientists. This behavioural theory emphasises the importance of social influences on the development of attitudes and the forming of behaviours (Bandura, 1986; Dudo & Kahlor, 2017). It explains how individuals acquire and maintain behaviours by observing others and how their perceptions of others will determine whether they too will adopt the behaviour in question. In addition, social cognitive theory also considers the effect of an individual's past experiences on her/his future behaviour. Bandura (1999:155) explains:

> In social cognitive theory, people are agentic operators in their life course, not just onlooking hosts of internal mechanisms orchestrated by environmental events. They are sentient agents of experiences rather than simply undergoers of experiences.

Bandura (1986) expounds his specific take on social cognitive theory, presenting a comprehensive theory of human motivation and action as these are shaped and controlled by environmental influences and internal dispositions. Bandura's theory proposes three core factors that influence human behaviour:

- **personal** factors, which depend on whether an individual believes in her/his own ability to perform the behaviour;
- **behavioural** factors, which are influenced by the response an individual receives after she/he had performed a behaviour; and
- **environmental** factors, which are related to aspects of the environment that influence the individual’s ability to complete a behaviour successfully.

These core factors interact and influence one another dynamically and bi-directionally in a “triadic reciprocal causation model” (Bandura, 1986:24), as shown in Figure 2.2. This implies that personal factors and the environment could influence behaviour, and vice versa.

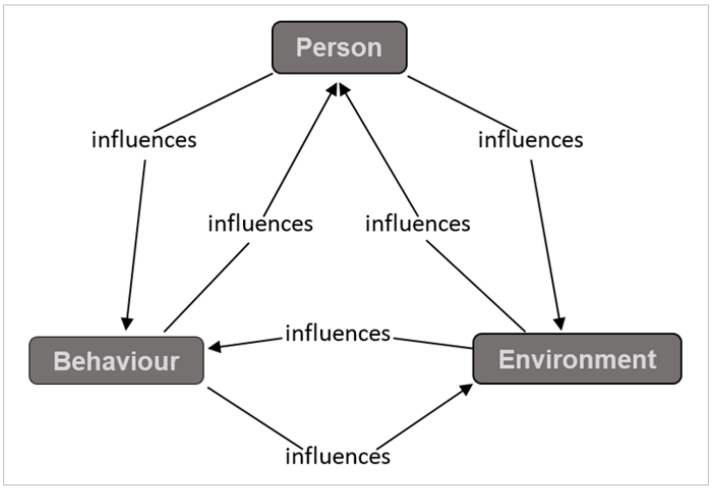

Figure 2.2: Triadic reciprocal causation model
(Source: Bandura, 1986:24)

A key component of social cognitive theory is that people learn by observing others (Bandura, 1977) and by noting the consequences of a behaviour. Their observation of whether a specific behaviour is rewarded or punished, will guide people’s own thinking (cognition) about that behaviour, as well as their own subsequent behaviours. That is, they choose to replicate or avoid a specific behaviour.[27] As such, reinforcements, expectations and self-efficacy are key constructs in social cognitive theory. ‘Reinforcements’ refer to the internal or external responses to a person's behaviour that affect the likelihood of continuing or discontinuing the behaviour. ‘Expectations’ refer to the anticipated consequences of a person’s behaviour. Self-efficacy refers to a person’s perceptions of her/his own abilities.

Social cognitive theory furthermore postulates that, even if individuals expect positive outcomes from a specific behaviour, they will only attempt it once they are confident that they are able to perform it successfully (Kraft, Rise, Sutton & Røysamb, 2005). This means that their behaviour is shaped by their perception of their own skills and competence (which links back to the concept of self-efficacy), and is dependent on the cooperation of others and the availability of resources. Action

[27] Lapinski and Rimal (2005) point out that people do not act solely on the basis of the popularity (or expected positive outcomes) of a behaviour. Sometimes people defy normative influences and use their own judgement to take an unpopular stance, despite group pressure and despite expected negative results.

is therefore a product of their expectations in terms of both outcome and efficacy (Bandura, 1977). Applying social cognitive theory to the communication behaviour of scientists therefore implies that contextual factors, such as organisational culture and the availability of communication funding and training, contribute to perceived behavioural control, that is, the perception of individual scientists of whether they could or could not perform a specific behaviour.

2.4. Relevant extensions to the theories

While the theory of planned behaviour is broadly applicable to human behaviour, several authors have suggested extensions and augmentations to increase its relevance and applicability to the case of the public science communication behaviour of researchers (Trafimow, Sheeran, Conner & Finlay, 2002; Poliakoff & Webb, 2007; Ajzen, 2011; Sommer, 2011). Dudo (2012) proposes a model for scientists' PCST behaviour based partly on the theory of planned behaviour, while Poliakoff and Webb (2007) suggest an augmented version of the theory of planned behaviour to measure scientists' beliefs about public engagement and to examine the relationships between these beliefs and participation decisions.

Personality traits, such as being extroverted, adventurous and social versus being shy, fearful and reclusive, influence the way people feel and act, and specifically the way they are perceived by others (Ajzen, 1988). Therefore, one could argue that generally observed personality traits should be included when the communication behaviour of scientists are studied. Reflecting on the link between personality and behaviour, Bandura (1999) describes personality as multifaceted, richly contextualised, and conditionally expressed in the diverse transactions of everyday life. The author argues against labelling people's personalities with a limited number of descriptive categories. Instead, he believes, an individual's personality is manifested in the way such person expresses her/his individuality and gives structure, meaning and purpose to her/his life. People do this by acting on their beliefs about themselves, their values, aspirations and construal of the world around them.

Poliakoff and Webb (2007) extended the theory of planned behaviour by adding **moral norms**, **fear** and **environmental factors** as constructs. They motivate for the addition of moral norms (an individual's perception of the moral correctness of a specific behaviour) by pointing out that taking part in public communication (or not) is likely to constitute a morally relevant situation for scientists, due to their access to public funding and privileged information. The addition of fear as a construct stems from its prominence in other behavioural theories as a powerful motivating influence on behaviour. Poliakoff and Webb (2007) point to the relevance of fear in terms of public communication by explaining that scientists may fear a negative response from their colleagues, tainting their scientific reputation, being misunderstood or misquoted, or repercussions from interest groups who are hostile to science.

In addition, Poliakoff and Webb (2007) argue that the constructs in their augmented theory of planned behaviour (focusing on individual beliefs) should be supplemented by a set of factors considering scientists' **work environment**.[28] It is also important to measure the influence of constraints such as time and money, since these factors affect the degree of control scientists have over participation in public science communication. Contextual factors are therefore suggested as an additional construct in their augmented version of the theory of planned behaviour. It is important to note, however, that these contextual factors (such as availability of funding or training) also contribute to perceived behavioural control (i.e. the perception of individual scientists of whether they could or could not perform a specific behaviour, depending on their own control over it and its perceived difficulty). Likewise, the extended theory of planned behaviour (Poliakoff & Webb, 2007) explains that behaviour depends on the individual's perception of whether the required resources and opportunities are available to execute the behaviour in question. Consequently, organisational culture affects scientists' interest and willingness to engage with external audiences.

Claiming "no existing theoretical model sufficiently captures the PCST process", and subsequently motivating for the need to include more factors that are likely to be associated with researchers' public communication behaviour, Dudo (2013:480) suggests additional constructs in his 'PCST process model'", including the concept of **medialisation**. 'Medialisation' refers to the phenomenon that science may be becoming increasingly media-oriented (Weingart, 1998) and that, consequently, media criteria become relevant in science (Peters, Heinrichs, Jung, Kalfass & Petersen, 2008; Rödder, 2011, Weingart, 2012).

The three stages whereby an individual scientist may adopt organisational concerns for media visibility, as suggested by Marcinkowski *et al.* (2014), are reminiscent of the factors that influence scientists' decisions to participate in public communication, as suggested by the theoretical framework of this study (see Figure 2.4). In the first place, scientists may become aware of the desire of their university for media publicity (institutional environment). Secondly, they may observe that colleagues care about media visibility (subjective normative beliefs). This may then result in a personal adoption of the concern for visibility (a change in personal attitude), which may lead to their decision to participate. It is therefore fitting to include medialisation as one of the factors that will have an influence on the public science communication behaviour of scientists, both directly (via their internalisation of the need to communicate, which changes their attitude towards the behaviour) and indirectly (via their response to institutional pressures and other external demands).

2.5. The social nature of communication

Both the theory of planned behaviour and social cognitive theory are socio-psychological theories with a strong focus on individual behaviour. Therefore, it is necessary to acknowledge that every behaviour is set in a specific context. A useful model to consider the broader context of public science communication is the communication model suggested by Riley and Riley (1959). This model

[28] Note than social cognitive theory (Bandura, 1986) similarly considers the influence of the social environment on human motivation (and therefore action or behaviour).

(see Figure 2.3) illustrates the sociological implications inherent to communication by presenting communication as a social system with interactions between communicators (C) and receivers (R), both embedded in a larger social structure (Riley & Riley, 1959:577). Both communicators and receivers are influenced by various primary groups, such as friends, relatives, colleagues, and the like. Messages flow in both directions between communicators and receivers.

Applying this model to public communication of science, scientists can be viewed as the communicators, with the public as receivers, a construction that closely resembles the so-called ‘deficit model’ of science communication (Brossard & Lewenstein, 2010). In this both, both the communicator and receiver are embedded in a larger communication landscape and socio-political environment. Many variables determine the flow of information, including researchers’ attitudes, institutional rules and the audience’s information demands.

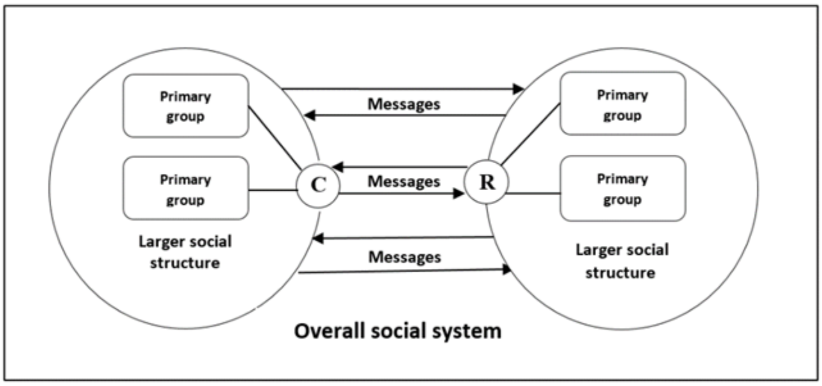

Figure 2.3: The Riley and Riley model of communication
(Riley & Riley, 1959:577)

2.6. Theories about the normative nature of science

The **norms** that guide if, when and how scientists communicate, proposed by Merton (1973) and also applied by the authors of the theory of planned behaviour (Fishbein & Ajzen, 2010), provide another perspective on the public communication behaviour of scientists. In line with views on the normative nature of science, the theory of planned behaviour identifies norms as “the perceived social pressure to perform or not to perform a behaviour” (Ajzen, 1991:188), and postulates that norms are significant predictors of behaviour.

Merton (1968) contends that normative imperatives are legitimised within institutional values, transmitted via principles and examples, and reinforced by sanctions. In other words, scientists figure out the norms of their profession by observing the behaviour of their peers and taking note of the rewards and penalties associated with certain actions. Within these two processes whereby scientists internalise norms – i.e. observing others and experiencing consequences for themselves – lies the difference between descriptive and injunctive norms.

Descriptive norms relate to the prevalence of a behaviour, in other words what an individual observes others are doing. Therefore, scientists’ descriptive normative beliefs will depend on whether they see their peers performing the behaviour (Poliakoff & Webb, 2007; Fishbein & Ajzen,

2010) and they are motivated to participate in outreach when they observe that respected colleagues and institutions are involved (Holland, 1999). This "socialisation process" is particularly pertinent in the case of young scientists (Martín-Sempere *et al.*, 2008:362). Poliakoff and Webb (2007) agree on the importance of descriptive norms, based on the evidence of its influence on behavioural intentions of scientists.

Injunctive norms depend on the perceived pressures to perform a specific behaviour and are therefore shaped by scientists' perceptions of whether others approve or disapprove of a specific behaviour (Lapinski & Rimal, 2005; Fishbein & Ajzen, 2010). Social sanctions are expected if others do not approve of the behaviour. It follows that scientists will avoid behaviour that they suspect will not meet with their peers' approval, and rather choose to do the things that they think are expected of them. Consequently, the perception that scientific colleagues disapprove of outreach activities, could be a major deterrent to their own participation (Andrews *et al*., 2005). Injunctive norms are particularly relevant to public science communication, since scientists are typically concerned about the approval of their peers. The perception that media prominence may tarnish a scientific career and that peers may disapprove of a high public profile, sometimes referred to as the 'Sagan effect' (Dean, 2009; Dudo, 2013; Martinez-Conde, 2016), is an example of an injunctive norm.

Jointly, descriptive and injunctive norms result in the **subjective norm**, which refers to the perceived social pressure to perform a specific behaviour, and the perception of whether a specific referent group would approve of the behaviour or not. Poliakoff and Webb (2007) point out that people are likely to have several referent groups, and the normative influence of friends and family may, for example, be more positive than that of academic colleagues.

2.7. Conceptual framework

The conceptual framework guiding this study focused on concepts and variables that have been shown to influence scientists' communication attitudes, motivations and behaviours, as well as the relationships between them. Relevant earlier studies were informed by different theoretical assumptions. Some of these studies focused on demographic variables or individual attitudes or scientists' perceptions of communication risks and benefits, while others looked at structural conditions that encourage or inhibit scientists' involvement in public communication.

Research in this field is largely based on large-scale surveys commissioned by funders or scientific associations (MORI, 2001; The Royal Society, 2006; BBSRC, 2014; TNS-BMRB, 2015). While such surveys may be valuable to help identify factors that motivate or constrain scientists when it comes to public communication about their work, Poliakoff and Webb (2007) point out that surveys are largely descriptive and lack a theoretical framework. As such, it is difficult to identify the relative importance of the influencing factors, and how these factors relate to each other. Further shortcomings of large surveys include that people are mostly not able to understand the underlying causes of their own actions, as well as the influence of post hoc rationalisation and recall biases (Poliakoff & Webb, 2007). Consequently, instead of asking scientists why they communicate with the public (or not), Poliakoff and Webb came up with a theoretical framework to measure scientists' beliefs about public engagement and to examine the relationships between these beliefs and their participation decisions.

Combining elements of social cognitive theory, the theory of planned behaviour and extensions to the theory of planned behaviour, as discussed above, I proposed a conceptual framework that underpinned the current study (see Figure 2.4). This framework was used to analyse the research literature in order to extract and categorise what we can learn from earlier research on this topic, as well as to guide the empirical component of this study. The framework proposes three clusters of factors (background, personal and contextual), which influence scientists' public communication behaviours. These three clusters of factors also influence one another. For example, a researchers' discipline (one of the background factors) is likely to influence her/his normative beliefs (one of the attitudinal factors). Similarly, behavioural beliefs (in the cluster of attitudinal factors) will be influenced by the availability of training and support (contextual factors).

2.8. Explanation of the factors in the conceptual framework

All the influencing factors reflected in the conceptual framework that underpinned this study (see Figure 2.4) were extracted from the theoretical basis for exploring communication behaviour, as discussed above. The factors were grouped into three clusters: background factors, attitudinal factors and contextual factors.

Cluster 1: In recognition of their influence on human behaviour, Ajzen (2011) suggests that **demographic background factors** should be added to the theory of planned behaviour. Accordingly, Van der Auweraert (2008) uses the theory of planned behaviour to understand the communication behaviour of scientists, but adds a cluster of person-related factors. The background factors included in the current study consist of career-related factors, such as a researcher's **broad field of research** and her/his **research productivity**, as well as the individual demographic variables, namely **age**, **gender** and **population group**. These are factors that are inherent to an individual researcher and that would not change if an individual moved to a different institution or other country.

Cluster 2: The cluster of **attitudinal factors** contains all the factors that are expected to influence scientists' feelings and perceptions (i.e. attitudes) regarding public science communication. It is therefore dependent on how they feel about the media and social media, whether they perceive a sense of duty to communicate, and how they perceive their own communication efficacy. It includes how scientists' attitudes are shaped by their own personalities and norms, as well as by their perceptions of the risks and rewards of communicating science. Jointly, these factors in the second cluster shape the overall attitude, whether positive or negative, of an individual researcher towards public communication of her/his research. All the factors in this cluster are intrinsic to the researcher and relate to how the researcher feels about a certain aspect relevant to public science communication. Typically, these individual feelings could change. For example, a researcher may become more positive about her/his own ability to communicate following a training course.

Cluster 3: To perform a behaviour, a person also needs opportunities and resources. That is why the third cluster of factors consider the **context** where scientists work and how this influences their ability and willingness to communicate. It groups together factors related to institutional culture, evaluation and medialisation. It also considers the influence of the national context, including the socio-economic and cultural environment, as well as the natural (biophysical) environment.

Jointly, these three clusters of factors contribute to scientists' perceptions of 'enablers' (motivators and rewards) or 'constraints' (risks and barriers) in terms of public science communication. This blend of encouraging and constraining factors shapes scientists' intention to communicate with public audiences, which will ultimately determine their participation, i.e. the actual public science communication behaviour, as illustrated in Figure 2.4 below.

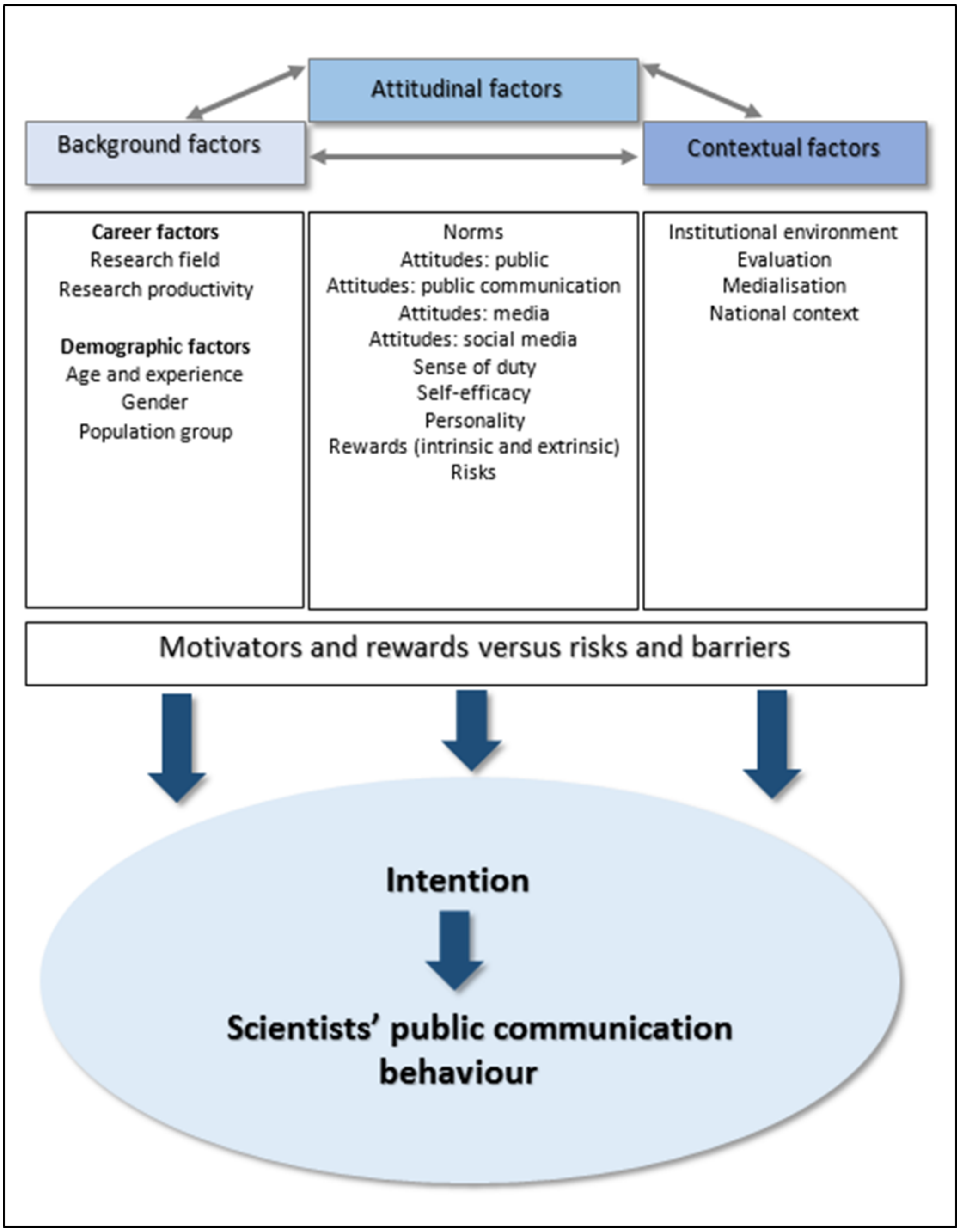

Figure 2.4: Factors that influence scientists' public communication behaviour: A conceptual framework (Source: Researcher's own compilation)

Chapter 3: Literature review: Public science communication by scientists

> ***The relationship between science and society is often represented in terms of misunderstandings, gaps to be filled and bridges to be built.***
> *(Bucchi & Trench, 2014a:2)*

3.1. Introduction

In order to answer my research question, a comprehensive review of relevant research literature and contemporary scholarly opinion about the factors that influence the public science communication behaviour of publicly visible researchers is provided in this chapter. The aim of the literature review was to distil key findings from pertinent studies published over the last 20 years[29] (1997–2016), complemented by related commentaries and insights from selected studies that date further back. In addition, the literature review helped to identify lingering uncertainties and knowledge gaps that are significant in the South African context.

Over the last two decades, science communication scholars have taken a particular interest in the role of academics in public life, resulting in a substantial volume of research in this field. These studies aimed to clarify, quantitatively or qualitatively, the enabling or impeding factors that influence researchers' involvement in public science communication.

Relevant studies were identified via purposive and exhaustive searches of academic journals relevant to the field of public science engagement, supplemented by searches in digital collections hosted by the Library and Information Services at Stellenbosch University, specifically using the Thomson Reuters Web of Science. The following keywords were used as search terms: outreach, public engagement, science communication, public visibility, scientists and public engagement. Furthermore, the following inclusion and exclusion criteria guided the literature search:

- Inclusion criteria: Empirical studies and reviews of the public communication/engagement behaviour (views, attitudes and activities) of scientists and the factors affecting their behaviour, including studies on how scientists view and use media and social media for public engagement, published in English as peer-reviewed articles, doctoral dissertations, books, conference papers or official reports.
- Exclusion criteria: Studies that focused exclusively on the motivations of scientists to engage policymakers and/or industry and/or schools and educators (not the general public), as well as studies about the behaviour of science communication professionals and/or journalists (i.e. not scientists).

[29] See Appendix 1 for the list of 107 studies. Since the factors affecting researchers' involvement in public science communication are sensitive to changes in societies and the communication landscape, only empirical research published over the last two decades were included in the literature review. In addition, I refer extensively to Rae Goodell's seminal study from 1975 presented as a unique series of case studies of visible scientists, and the only study that shed light on the personality traits of high-profile science popularisers (Goodell, 1975).

A total of 107 studies, published between 1996 and 2016 (listed in Appendix 1) were analysed in depth in order to distil current knowledge on the factors that affect the public science communication behaviour of scientists. Some of these studies were large-scale surveys within and across countries looking at the nature and frequency of science communication (The Royal Society, 2006; Pew Research Center, 2015a; TNS-BMRB, 2015). Others explored the dynamics of scientists' interactions with journalists (Peters *et al.*, 2008b; Dunwoody *et al*., 2009), interactions between scientists and online audiences (Liang *et al.*, 2014; Lo & Peters, 2016) or face-to-face engagements between scientists and the public at events such as science fairs and science cafés (Martín-Sempere *et al.*, 2008; Mizumachi *et al.*, 2011).

Some investigations homed in on scientists in specific fields, for example biomedical researchers (Dudo, 2013; Dijkstra, Roefs & Drossaert, 2015), nanoscientists (Dudo, Kahlor, AbiGhannam, Lazard & Liang, 2014; Aykurt, 2016) or neuroscientists (Allgaier *et al*., 2013a; Koh *et al*., 2016). Researchers have also explored the influence of biographical factors, such as gender (Crettaz Von Roten, 2011) and discipline (Ecklund *et al.*, 2012), while others focused on scientists' motivations when it comes to public communication (Dunwoody *et al.*, 2009; Tsfati *et al.*, 2011).

Turning to the context where scientists operate, researchers have investigated the influence of the institutions where scientists work (Jacobson *et al.*, 2004; Marcinkowski *et al.*, 2014; Entradas & Bauer, 2016), as well as regional differences (Kreimer *et al*., 2011; Crettaz Von Roten & Goastellec, 2015).

Informed by the supporting behavioural theories and the conceptual framework guiding this study (see Chapter 2), findings from the literature review were grouped into three broad clusters:

- background factors (a combination of career-related and socio-demographic factors);
- personal (attitudinal) factors; and
- contextual (environmental or institutional) factors.

These factors were reviewed in Chapter 2. Given South Africa's population diversity, I added one additional factor (namely **population group**), which was not found in the literature. Importantly, the theory of planned behaviour recognises race (or ethnicity) as one of the relevant background factors to explore in terms of its effect on human behaviour (see Figure 2.1).

3.2. Literature review: Background factors

3.2.1. Field of research (or research discipline)

> ***The gap may be a steep canyon in the sciences, but a smooth valley in the humanities and social sciences.***
> *(Peters, 2013:14103)*

3.2.1.1. The origins of scientific disciplines

Branches of knowledge about the natural world can be traced back to ancient times, and the earliest scientists commonly worked across many of these fields (Schummer, 2009). Over the past 200 years, the exponential growth in scientific knowledge has fragmented science into numerous disciplines, sub-disciplines and super-specialised research fields. Schummer (2009:56) explains the concept of 'discipline' (from the Latin *disciplina*) as follows:

> Students (disciples) learn a doctrine (a discipline) by obeying strict (disciplinary) rules of a school (a discipline) and by practising self-control (discipline). A discipline is not simply an abstract set of information, but both a body of knowledge that is taught at a school and the social context of the school. Disciplinary knowledge requires a social context of transmission and education and a social body that reproduces itself by educating students to become future teachers. A scientific discipline thus comprises both cognitive and social aspects.

Scientific disciplines, as we know them today, only emerged in the 19th century, and have been shaped by historical, geographical and institutional variations (Ziman, 2000; Becher & Trowler, 2001; Weingart, 2010). As disciplines evolve and mature, an associated culture and set of sociological and epistemological factors, unique for each discipline, emerge (Kuhn, 1962). Schummer (2009) highlights the social aspect of a discipline, referring to a body of scientists who see themselves as members of (and committed to) a specific community. Weingart (2010) points out how disciplines, once they are institutionalised, structure the production, distribution and application of knowledge.

3.2.1.2. Involvement across scientific disciplines

Communication is one of the key characteristics that define a discipline. In fact, Weingart describes disciplines as "social communities bonded by communication" (Weingart, 2010:8), while Weingart and Stehr (2000:xi) refer to disciplines as "the intellectual structures in which the transfer of knowledge from one generation to the next is cast". Disciplinary communication is inward-focused and self-referential, to the extent that it may even be difficult for scientists from different disciplines to communicate with one another. Already in 1959, Snow commented on the diverging paths taken by the arts and sciences and the resulting gulf of incomprehension between literary intellectuals and natural scientists (Snow, 1959; Van Dijck, 2003).

Several studies found that, collectively, researchers in the arts, humanities and social sciences are more active in public communication than those in the natural and physical sciences, mathematics and engineering. Such findings have been reported in Norway (Kyvik, 2005), France (Jensen & Croissant, 2007; Jensen, 2011), Argentina (Kreimer *et al.*, 2011), the Unite States (Pew Research

Center, 2015a), the United Kingdom (TNS-BMRB, 2015), as well as in a 13-country study (Bentley & Kyvik, 2011). Social scientists also interact with the media more frequently compared to natural scientists (Peters, Spangenberg & Lo, 2012; Peters, 2013).

Finer analyses of comparative public engagement across disciplines reveal that some narrow disciplines outperform others. Studies point to low levels of public engagement for researchers in the fields of chemistry and engineering, while environmental scientists are generally more engaged (Jensen & Croissant, 2007; Searle, 2011; Besley, Oh & Nisbet, 2013; Entradas & Bauer, 2016). Furthermore, physicists, chemists, materials scientists and engineers are almost absent in media interactions (Jensen, 2011; Torres-Albero *et al*., 2011).

Disciplines also shape the type of communication activities in which scientists participate (Jensen & Croissant, 2007; Chikoore *et al.*, 2016; Entradas & Bauer, 2016). Natural scientists are especially active in schools and public events, while social scientists prefer media interactions and public speeches (Jensen, 2011, Kreimer *et al*., 2011, Torres-Albero *et al*., 2011). This division (natural sciences favouring informative activities and social sciences favouring dialogue) is confirmed by Entradas and Bauer (2016). By contrast, surveys by Besley *et al. (*2013), Ecklund *et al*. (2012), Davies (2013b) and Chikoore *et al*. (2016) reveal little variation in the level of researchers' public communication involvement according to their discipline.

3.2.1.3. Differences in disciplinary norms

The norms governing scientific discipline are crucial determinants influencing if and how scientists communicate in public (Dunwoody & Ryan, 1985; Johnson *et al.*, 2014). Norms are generally strict in the natural sciences, and natural scientists are therefore "less likely to deviate from the norms of science and scholarship than are social scientists" (Hagstrom, 1965:11). For example, natural scientists are expected to have an excellent scientific reputation and consult with their institutional media offices before they talk in public about their work. Natural scientists are expected to limit their media interactions to serious media outlets known for high-quality science reporting (Peters *et al.*, 2012).

Furthermore, the Ingelfinger rule[30] is widely enforced in the natural and physical sciences, but less so in the humanities and social sciences. This makes researchers from the natural sciences generally reluctant to share information about unpublished research, something that is less problematic for social scientists and humanities scholars (Peters *et al*., 2012). Moreover, the natural sciences generally have tight knowledge requirements, leading to a sharp demarcation between these fields and the outside world (Peters, 2013).

[30] The 'Ingelfinger rule' refers to the policy of scientific journals not to accept manuscripts for publication when the research has already been covered by the public media. *Physical Review Letters* set a precedent in 1960 by announcing that it would reject articles whose main contents had already appeared in the daily press. A similar philosophy was put forward by Ingelfinger in 1970, in his role as editor of the *New England Journal of Medicine*. The policy became known as the "Ingelfinger rule" (Goodell, 1977:130).

Social scientists are therefore less constrained in their public dissemination activities when compared to their counterparts in the hard sciences (Dunwoody & Ryan, 1985) and it is comparatively easier for soft disciplines to play by the rules of the media in order to become public experts and opinion leaders (Wien, 2014).

3.2.1.4. Differences in social distance

Some disciplines (and topics within these disciplines) resonate closely with public interest and touch people's lives more than others, thereby generating demand for experts in these fields to engage with the public. Already in 1975, Goodell noted that social scientists and biologists, rather than physicists, were especially visible, ascribing it to the tendency for the public to be more interested in topics which are "closer to home, less abstract, more human" (Goodell, 1975:32). Commenting on the fame achieved by the St Louis sex researchers William Masters and Virginia Johnson, Goodell noted that sex is the ultimate hot topic that will attract public attention.

Studies continue to show that natural scientists working in fields that resonate with societal interest, such as research on the human brain, genetics and biodiversity, are considerably more active in the public sphere than those working on fundamental, esoteric fields (Mathews *et al*., 2005; Jensen *et al*., 2008). Generally, social sciences and humanities are likely to be a part of everyday life, making it easier to construct relevance for lay audiences compared to the hard sciences that are often perceived as remote from societal concerns (Peters *et al*., 2012). Moreover, the resonance of social sciences with news values, such as controversy and human interest, attracts media attention and favours social scientists to become commentators, analysts and opinion leaders, eventually maturing into public intellectuals,[31] roles that are comparatively harder for natural scientists to fill.

Physics, for example, has long been viewed as "alien" and "disconnected" from everyday life (Morus, 2009:4). As a result, physicists collectively are normatively constrained when it comes to engaging with broad society. Many physics researchers view outreach as something that is peripheral to their core academic task, and those who are actively involved in outreach occupy a marginal status. Interestingly, though, some astronomers and cosmologists enjoy a high public profile. The 19th century astronomer Richard Proctor gave thousands of lectures around the world. More recently, people like Patrick Moore, Carl Sagan, Martin Rees and Neil deGrasse Tyson became well known (West, 2009; Fahy, 2015). Stephen Hawking has written bestsellers, starred in numerous television shows, travels the world to give public talks and writes children's books with his daughter (West, 2009; Gazan, 2013). In the case of astronomy, it is possible that public interest, fuelled by the cultural significance of the night sky and widespread fascination with the universe, creates such a demand for scientists to engage with the public that it overshadows the restrictive cultural norms

[31] Note that, according to Cassidy (2014), the nature of social science expertise makes it hard for researchers in these fields to gain authority in the eyes of the public, especially at first, and legitimacy as experts in the eyes of the media.

of the discipline[32] (West, 2009). But, there is also evidence that most astronomers enjoy public outreach and would like to spend more time on it (Dang & Russo, 2015).

3.2.1.5. Disciplinary differences in scientists' communication views

Researchers' field of work may influence how they view and value public communication. For example, scientists working in traditional social science disciplines (such as anthropology) typically do not regard outreach as an integral part of their scholarly work, but rather as something they do for the public good. By contrast, those who work in applied social sciences (such as urban planning) regard outreach as fundamental to their scholarly work (Lunsford, Church & Zimmerman, 2006).

Most natural scientists view outreach as a form of service to society, rather than as a scholarly activity, while the majority of scholars in the arts, humanities and social sciences value public engagement as a core component of their work (TNS-BMRB, 2015).

Furthermore, most natural scientists doubt whether public dialogue could provide them with new perspectives on their research. By contrast, humanities scholars readily accept public dialogue as a value-adding activity (Vetenskap & Allmänhet, 2003). In addition, more social scientists, compared to natural scientists, think that media coverage is valuable and may enhance their careers (Pew Research Center, 2015a).

Some disciplines display a "strong sense of duty to go public" (Marcinkowski *et al*., 2014:60), for example biomedical scientists perceive a higher sense of duty to communicate their work to public audiences compared to non-biomedical researchers (MORI, 2001). This is equally evident in a case study of cancer research and the mass media (Smith, Singer & Kromm, 2009). By contrast, some disciplines cling to traditional scientific norms, leading them to nourish a "touch-me-not" attitude toward journalists, and to question the academic reputation of scientists routinely featured in the mass media (Dunwoody, 1986:8). Smith *et al. (*2013:3) agree that some disciplines harbour a cultural bias against public engagement "which not only fail[s] to reward such efforts but actively discourage[s] them".

3.2.1.6. Selective media interest

Scientific disciplines that are perceived to be close to everyday life, or those with pronounced moral, social and economic dimensions and links to controversy, attract media interest (Jensen & Croissant 2007). This selective media interest helps to explain why some researchers are more media-active than others (European Commission, 2007; Peters *et al.*, 2012) since a perception of public and media interest stimulates scientists to communicate (Pew Research Center, 2015b).

[32] The International Astronomy Union, an eminent, global scientific association, pro-actively and visibly supports public astronomy communication through activities, grants and events, and publishes its own peer-reviewed journal for astronomy communicators – see http://www.capjournal.org/

Journalists also have different expectations of scientists in hard versus soft disciplines. Journalists typically approach natural scientists for news about advances in cutting-edge knowledge, while they contact social scientists for comments on topical issues (Peters *et al*., 2012; Wien, 2014). Social scientists, “uniquely drawn by their expertise to cast a critical eye on the social norms and political practices in the society”, are therefore likely to adopt the role of public intellectuals (Kyvik, 2005:295).

Peters *et al*. (2012) propose that differential power relationships help to explain differences in media interactions across disciplines. In the hard sciences, the generation of new knowledge is reserved for those on the inside (i.e. scientists only), while knowledge in the social sciences are often co-created by many role players, including lay people. As such, a claimed monopoly in defining truth offers a power resource for those in the hard sciences, more so than for scientists in the soft disciplines.

Studies from the 1980s highlight differences in the way journalists treat natural and social sciences, and particularly highlight negative journalistic attitudes towards social sciences (Dunwoody, 1980; Weiss, 1985; McCall, 1988). Stories about physics, astronomy and medicine attracted the attention of specialist science reporters, but social sciences were often regarded as “garbage sciences” not worthy of special expertise (McCall, 1988:91). However, editors mostly preferred social science stories because of their wider public appeal, and social scientists were generally found to be more available to the press, more cooperative towards journalists and more frequently contacted by journalists (Dunwoody & Scott, 1982; Dunwoody & Ryan, 1983).

Studies comparing the media attention across soft and hard sciences show that media interests shift over time. A longitudinal study of science coverage in the UK press (1946–1990) illustrates that hard science news dominated initially, but news and stories about social sciences and humanities became more popular towards the end of this period (Bauer, 1995). Other surveys confirm that coverage of natural science achievements made way for stories about politics, crime and moral issues. Over time, journalists increasingly preferred to interview social scientists and humanities scholars (Hansen & Dickinson, 1992; Albaek, Christiansen & Togeby, 2003).

In general, research about the media coverage of science has focused mostly on how natural sciences are reported, with inadequate attention paid to social science coverage (Schäfer, 2009; Osrecki, 2012). This is curious, as Cassidy (2014) points out, since researchers doing media content analyses are typically social scientists. Furthermore, outputs from social science research, such as crime figures, census data and economic analyses, contribute significantly to non-specialist media coverage of science. Despite limited research evidence, indications are that social sciences are poorly represented and that social science experts are relatively invisible in the mass media.

3.2.1.7. More disciplinary-based differences

There are further suggested explanations for variations in researchers’ public science communication activity per discipline. Practical considerations may influence how researchers view the need to communicate with the public. For example, engagement is a core activity for medical scientists who use it as a means of recruiting research cohorts (Watermeyer, 2011). Additionally, scientific jargon and the esoteric nature of natural/physical sciences may make it challenging to translate its knowledge into plain language that would be comprehensible to non-specialists (Bentley & Kyvik, 2011; Peters *et al*., 2012; Peters, 2013). Furthermore, some research fields are much larger than others (for example, there may be many more geneticists than historians in a specific country) with the result that media interest is simply spread over a larger number of individual sources (Peters *et al*., 2012).

Historical differences across disciplines also affect researchers' current public communication behaviour. Prior to 2008, science communication surveys focused on science, technology, engineering and mathematics disciplines, with the result that public engagement in the arts, humanities and social sciences were under-researched (Burchell, 2015). Moreover, institutions favoured natural science disciplines when promoting public engagement activities in high-level reports, despite the fact that similar kinds of outreach activities (media work, public lectures, debates, literary and arts festivals, working with galleries, etc.) were part of the arts, humanities and social science landscape for many years. Lastly, it has been shown that the visibility of scientists and their work rises and wanes as topics move in and out of vogue and as the mass media favour new topics that capture the public imagination (Goodell, 1975).

3.2.2. Research productivity

> ***We have shown that if you randomly select a scientist and ask her or him whether she or he is active in dissemination, a positive answer is a sign of higher bibliometric indicators.***
> *(Jensen et al., 2008:532)*

The notion that scientists who are active popularisers and public communicators are "not good enough to do real science" (The Royal Society, 2006:11) has been consistently contradicted by research looking into the scholarly outputs of scientists and their public engagement behaviours. Despite the fears that public engagement will take resources – principally researchers' time – away from research, empirical investigations suggest that there is a positive correlation between scientific productivity (academics' publication counts, as quantified by bibliometric indicators) and public communication activities (David, 2002; Jensen *et al.*, 2008; Riise, 2008; Jensen, 2011; Wigren-Kristoferson, Gabrielsson & Kitagawa, 2011).

Already in 1982, Dunwoody and Scott demonstrated a positive relationship between scientists' professional status and the number of media interviews they grant. Scientists with the highest number of research outputs also write more popular articles compared to their less prolific colleagues (Kyvik, 2005; Bentley & Kyvik, 2011). In addition, productive scientists are in demand as media sources, since journalists prefer to contact seasoned scientists in leadership roles, and these leading scientists generally welcome interactions with journalists (Dunwoody *et al.*, 2009).

Consequently, academic status is regarded one of the most reliable correlates of frequency and attitude in terms of media collaboration.

Based on a temporal exploration of the public engagement activities of French researchers, Jensen *et al*. (2008) and Jensen (2011) present emphatic evidence that scientists who are top performers academically, are also actively engaged in wider dissemination of their work. Their communication activities are driven by external demand, such as requests for media interviews and public talks, confirming that the scientific elite is more visible to the outside world and consequently more sought after as public speakers and media sources than their peers. Leading scientists have the legitimacy to speak in public as representatives of their institutions.

Wigren-Kristoferson *et al. (*2011) conclude that high-performing researchers are distinct from other academics, based on their higher level of involvement in third-stream activities, which include public communication about their work. The authors suggest a virtuous and cyclical connection between high-quality research and public dissemination, with the motivation of the individual scientist to excel as the driving force fuelling knowledge production and outreach. Dudo (2012) confirms that scientists with a higher status (such as a higher career level and more publications) are also more involved in public science communication. These findings echo the comments by Goodell (1975) that the characteristics leading to public visibility are often similar to those demanded of success within science, such as ambition, energy, creativity, aggressiveness and intelligence.

High-quality research may even be a pre-condition for public visibility, since peers are more forgiving of a high media profile when the researcher has a strong scientific reputation[33] to back up the public visibility (Goodell, 1977). Findings from Rödder (2012) and Peters (2013) validate the normative expectation that scientists interacting with the mass media should have excellent professional reputations. In other words, as long as media prominence is linked to scientific achievement, visibility will enhance rather than hinder, a scientific career path. However, the science community is highly critical of public visibility in the absence of scientific credibility. Therefore, Rödder (2012) suggests that scientists manage their ambivalence about visibility by grounding their media prominence in scientific achievement. Correspondingly, Goodell (1975:178) argues:

> In some cases, criticism has had a very positive effect on visible scientists' productivity. Hardly deterring them, it spurred them on to write and speak more, explain their views better, strengthen their position.

Reflecting on the synergistic relationship between high-profile scientists and journalists, Goodell (1977) notes that visible scientists welcome publicity for their ideas and, instead of viewing reporters as parasites using scientists, visible scientists use reporters to gain influence and build a public profile. Consequently, these scientists go to great lengths to cooperate with the press, and are tolerant of the failings of the media.

[33] Explaining why scientific reputation often preceded public visibility, Goodell (1975) demonstrates that scientists who already have a reputation in their field have an advantage in terms of attracting media visibility.

3.2.2.1. Scholarly journals and the visibility of researchers

In the competitive media landscape of today, prestigious scientific journals contribute to the public visibility of scientists and may boost the profiles of research-productive scientists. Prominent scientific journals, particularly *Science* and *Nature,* selectively issue press releases to accompany some of the research articles they publish (Trench, 2007). These press relations efforts of scholarly journals ensure that featured articles attract media attention that extend far beyond the science community. Consequently, publishing a scientific article may be a powerful catalyst for public visibility.

Franzen (2012) claims that editorial decisions at some journals are not solely based on scientific merit, but are influenced by the perceived newsworthiness of the research, meaning that only some research articles will achieve public visibility in this way. When scholarly journals prioritise publicity for the contributions of leading scientists, it enhances the visibility of already prominent scientists. This is reminiscent of the so-called 'Matthew effect[34]' in science described by Merton (1968).

It seems logical to suggest that highly productive scientists may also be involved in public communication, simply because they have additional new content and ideas to share with external audiences. The efforts of professional science communicators at universities and scholarly journals will add to the opportunities that highly productive scientists will have to promote their findings.

When scientists publish articles that have potential news value or media appeal, institutional media officers collaborate with journals to attract media interest. They do this by adding high-resolution photographs, infographics and broadcast-quality video clips. PR officers assist journalists to access and interview the authors, thereby increasing the likelihood of media exposure.

3.2.3. Age and experience

> ***Most popularisers are well advanced in their careers before venturing into the public eye – indeed most of them seem to be strikingly eminent.***
> *(Charlton, 1990:38)*

A researcher's age, level of seniority and past experience influence the frequency and nature of her/his involvement in public science communication, with younger scientists generally less involved than their older colleagues. Several UK surveys consistently found that younger researchers are less likely to communicate their research to the public, compared to their older colleagues in more senior academic positions (MORI, 2001; The Royal Society, 2006; Bauer & Jensen, 2011; TNS-BMRB, 2015; Chikoore *et al*., 2016). Similarly, US scientists who have reached a certain career status are more involved in public communication than their younger peers (Dunwoody *et al*., 2009; Dudo, 2013) and the public communication activities of Swiss scientists peak relatively late in their careers, i.e. between the ages of 45 and 59 (Crettaz Von Roten, 2011). Similarly, Argentinian researchers

[34] The so-called 'Matthew effect' within the reward and communication systems of science explains why well-known scientists frequently get more credit compared to researchers that are less well known, despite the fact that their work may be of similar nature and quality (Merton, 1968).

become more involved in public communication as they reach more senior career levels (Kreimer *et al*., 2011). A temporal study of French scientists found that, at a given position, popularisation activity diminishes with age, but strongly increases with increasing seniority, which suggests that the level of seniority of scientists might matter more than age (Jensen, 2011).

Generational differences in how scientists view the public help to shape their involvement in public science communication (Searle, 2011). Older scientists are generally more inclined to believe that people are interested in science and their specific discipline, while junior scientists are less convinced of public support for science and generally believe that people would not be interested in science or in their specific field of research (Vetenskap & Allmänhet, 2003).

A track record of public engagement (in particular experience of media interviews) emerged in several studies as an important factor that increases scientists' confidence in pursuing public engagement opportunities (Pearson *et al*., 1997; Blok, Jensen & Kaltoft, 2008). Researchers with more experience feel better equipped to communicate both the scientific facts and the implications of their research, while junior scientists are generally uncertain about their own communication prowess (MORI, 2001; The Royal Society, 2006; Jensen *et al*., 2008; TNS-BMRB, 2015).

Two Australian studies done more than a decade apart (Gascoigne & Metcalfe, 1997; Metcalfe & Gascoigne, 2009) confirm that media-experienced scientists are confident and positive about media interaction and engage constructively with journalists. UK scientists agree that prior experience is the best way to gain public communication confidence (TNS-BMRB, 2015). Furthermore, scientists with experience of media work place a high value on media training and communication incentives from research funders (MORI, 2001), while scientists who have frequent contact with journalists enjoy media interactions more than their colleagues (Peters *et al.*, 2008a; 2008b). Perhaps the strongest evidence that participation in public engagement leads to increased involvement over time comes from the statistical analysis of the outreach activities of the same group of 7 086 French scientists (Jensen, 2011), which demonstrated a 60% increase over six years (2004–2009) (Jensen, 2011).

If experience of public engagement boosts confidence, inexperience can be a constraint, making junior scientists uneasy about public engagement (Bond & Paterson, 2005). A Japanese study found that participating early-career scientists were anxious and apprehensive about taking part in public events, and felt pressurised by perceived expectations to answer questions about issues of science outside their own research area (Mizumachi *et al*., 2011). Young researchers might need more help with public communication, and they are mostly keen to work closely with specialist science communicators (TNS-BMRB, 2015).

Poliakoff and Webb (2007) confirm that previous experience is a major driver of future intent to participate in public engagement, leading the authors to conclude that taking part in outreach activities in the early stages of a research career increases the likelihood that a scientist would sustain future participation. Based on this belief, UK research councils encouraged PhD students to become involved in science engagement activities (Pearson, 2001).

3.2.3.1. Normative influences linked to age, seniority and experience

The general expectation that older, established scientists who have the knowledge, time and skills to do so, should step forward when the media calls (Goodell, 1975; Greenwood & Riordian, 2001; Searle, 2011) may stem from the norms that govern the behaviour of scientists at different stages of their careers. Goodell (1977) suggests certain rules for scientists who wish to communicate with the general public, including that scientists should try to postpone public outreach efforts until their productive research lives are over. The high-profile popularisers featured in Goodell's (1975) classic study of visible scientists all achieved tenure first, followed by a high public profile. Furthermore, the author notes, once scientists reach a certain status, they are not concerned about whether their peers will approve of their public prominence.

By contrast, younger scientists who lack status in their work environment and who are under pressure to prove themselves, may prioritise academic progress and refrain from public engagement (MORI, 2001; Jensen *et al*., 2008; Horst, 2013). Moreover, young scientists may avoid media exposure because they fear negative consequences, in particular disapproval from their supervisors (Van der Auweraert, 2008; Rödder, 2012). Even senior academics who regard public communication as important, often do not encourage younger colleagues to get involved, fearing the effect on their careers (Burchell *et al*., 2009). Therefore, Rödder (2009) argues, young scientists are not necessarily media-shy, but they avoid publicity because of normative expectations.

Notably, some mid-career and senior scientists are likewise concerned about the potentially detrimental effect that outreach activities may have on their academic careers (McCann, Cramer & Taylor, 2015).

3.2.3.2. The effect of age on public science communication

Depending on their age, scientists prefer different types of public science communication activities. Older scientists favour media interactions and the opportunity to appear on television or radio shows (Kreimer *et al*., 2011), and are more involved in popular science writing (Kyvik, 2005; Bentley & Kyvik, 2011; Crettaz Von Roten & Goastellec, 2015). Research leaders are sought after as media sources and frequently contacted by journalists (Peters *et al.*, 2008b; Dunwoody *et al.*, 2009; Petersen, Anderson, Allan & Wilkinson, 2009; Bucchi & Saracino, 2012). They are more likely to get involved in writing press statements about their research (TNS-BMRB, 2015). Young scientists are more involved in collaborations with schools via public talks, science fairs, open days and mentoring of learners (MORI, 2001; Andrews *et al.*, 2005; Kreimer *et al*., 2011; TNS-BMRB, 2015). Young scientists have an advantage in digital media environments and generally make excellent use of social media (European Commission, 2007; Claessens, 2008; BBSRC, 2014; Pew Research Center, 2015a). Young scientists are more aware of citizen science and attach more significance to the value and potential influence of these emerging engagement platforms compared to their senior colleagues.

Junior and senior scientists have also been found to be motivated by different communication objectives. Senior scientists focus on attracting funding and advancing their own careers (McCann *et al*., 2015), as well as defending science against public irrationality (Kreimer *et al*., 2011). Senior scientists more readily accept personal responsibility for public engagement (MORI, 2001; Burchell *et al*., 2009) and therefore are more likely to be motivated by a sense of duty compared to younger colleagues (Martín-Sempere *et al*., 2008). Contrastingly, young scientists prioritise enjoying public interactions and getting positive responses from their audiences, while improving their own teaching skills (Andrews *et al*., 2005; Searle, 2011; McCann *et al*., 2015). Consequently, they focus on communication designed to excite public audiences (Dudo & Besley, 2016).

In contrast with views that favour older scientists as prime candidates for public communication about their work, some scholars are of the opinion that younger scientists are increasingly attaching high value to public engagement as part of their career and life aspirations (Hoffman, 2016). Young scientists acquire the confidence and skills to engage with external audiences early in their careers. Gregory and Miller (1998) point out that previous generations of young researchers were told that their place was in the laboratory, while the current generation of scientists who work in increasingly competitive environments and who face communication demands from funders and employers, are being coached in communication skills. In the past, the authors add, scientists were brought up in a culture which expected good science to be accessible only to the scientific elite, while the new challenge is to make science accessible to non-specialist audiences also.

Martín-Sempere *et al*. (2008:362) report that young scientists no longer view popularisation as a tedious or duty-driven activity. Instead, they are motivated by the cultural and aesthetic dimensions of public communication of science and participate "as a result of the socialization process to which they are subjected during work on their advanced degrees". Dunwoody *et al*. (2009) agree that the dominance of senior scientists in public engagement, particularly as far as media interaction is concerned, is likely to change as universities increasingly invest in developing the communication competencies of graduate students. The authors suggest that the growing popularity of public communication training programmes indicates that young scientists increasingly see the value of public engagement and they are likely to integrate these skills into their academic portfolios.

3.2.4. Gender

> ***Research on recruitment processes has shown that engagement towards society tends to be valued in the case of a male portfolio, but criticised when part of a woman's portfolio.***
> *(Bureau de l'égalité, 2007, quoted in Crettaz Von Roten & Goastellec, 2015:25)*

Much has been written about gender imbalances in higher education and the inherent inequality in the challenges faced by men and women in science careers. The dominance of men at higher levels of the academic hierarchy is well documented, as is the evidence for a general structural bias against women in science and the failure to recognise contributions by female scientists (Blickenstaff, 2005; Ceci, Williams & Barnett, 2009; Ceci & Williams, 2011).

Due to the pervasive nature of gendered processes throughout the practice and culture of science, it is reasonable to expect that male and female scientists may have different views and experiences when it comes to public outreach (Johnson *et al*., 2014). It has been suggested that the involvement of female scientists may be hindered by the so-called Matthew effect, but also by the associated Matilda effect, which describes the systemic bias against women in science and the systematic under-recognition of their contributions (Rossiter, 1993). Consequently, gender is often included as a variable when researchers explore the public communication behaviour of scientists.

3.2.4.1. Participation of male and female scientists

The arena of publicly visible scientists is dominated by men (Fahy & Lewenstein, 2014). Goodell (1975:7) identified only two women (Margaret Mead and Jane Goodall) in her list of 20 highly visible scientists,[35] while Fahy (2015) included only one woman (Susan Greenfield) in his chronicles of the lives of high-profile scientists, *The new celebrity scientists.*[36]

Research evidence is inconclusive about gender as determinant of science communication activity. Several studies show that male scientists have higher levels of public engagement activity compared to their female colleagues (The Royal Society, 2006; Crettaz Von Roten, 2011; Kreimer *et al*., 2011), while men also appear to be more willing to participate in online engagement (Besley, 2015a). However, a similar number of studies show that female researchers take the lead in outreach activities (Andrews *et al.*, 2005; Jensen *et al.*, 2008; Jensen, 2011; Ecklund *et al.*, 2012). As an example, a large-scale UK survey pinpointed senior female researchers as the group most likely to be highly active in public science engagement (TNS-BMRB, 2015).

3.2.4.2. Gender differences in attitudes and objectives

Men and women generally share a positive view of science outreach (Crettaz Von Roten, 2011), with women in some instances more positive about outreach than their male colleagues (TNS-BMRB, 2015). However, male and female scientists have different objectives when they engage with the public and they perceive dissimilar benefits from their involvement. For example, men, more often than women, think that dialogue with the general public provides them with new perspectives on their own research (Vetenskap & Allmänhet, 2003). Women are more likely to agree that public engagement could lead to new research contacts and that scientists have a moral duty to engage

[35] The twenty most visible scientists as identified by Goodell (1975:7) in decreasing order of public visibility were BF Skinner, Margaret Mead, Jonas Salk, Wernher von Braun, Linus Pauling, Paul Ehrlich, Isaac Asimov, Jane Goodall, Albert Sabin, William Shockley, Noam Chomsky, Barry Commoner, James D Watson, Edward Teller, Rene Dubos, Glenn Seabourg, Arthur Jensen, Harold Urey, George Wald and Joshua Lederberg.

[36] The eight celebrity scientists featured by Fahy (2015) were Stephen Hawking, Richard Dawkins, Steven Pinker, Stephen Jay Gould, Susan Greenfield, James Lovelock, Brian Greene and Neil deGrasse Tyson.

with the public, while women are also generally eager to acquire science communication training and include public engagement in research assessments (The Royal Society, 2006).

3.2.4.3. Proposed explanations for gender differences

Researchers propose a range of potential explanations for the observed gender-based differences in the involvement of researchers in public science communication, including normative influences, which cause scientists to respond differently to the public engagement activities of male versus female colleagues (Crettaz Von Roten & Goastellec, 2015). Outreach is sometimes perceived as a stigmatised task that is routinely delegated to women (Johnson *et al*., 2014), and there are concerns that public engagement could hinder the academic progress of female scientists (Ecklund *et al*., 2012). Consequently, women who get involved in public engagement are frequently confronted by negative stereotypes and are even warned to stay away from engagement activities or risk not being taken seriously (The Royal Society, 2006).

Furthermore, Searle (2011) shows that male and female scientists perceive different barriers when it comes to public life. Women are hindered by personal factors such as a perceived lack of confidence and knowledge, while men are more concerned about workplace policies, legislation, contracts or regulations, as well as restrictions and sensitivities around information. Female scientists are often motivated by the idea of attracting young women to science, and may experience pressure to act as role models (Johnson *et al*., 2014; TNS-BMRB, 2015). By contrast, men are especially in demand as media sources (Torres-Albero *et al*., 2011; Crettaz Von Roten, 2011).

3.2.5. Population group

None of the 107 studies (see Appendix 1) reviewed for evidence of the factors that influence scientists' communication behaviour addressed the question of population group. This is expected, since there is no theoretical basis to suggest that population group in itself would have an influence on whether scientists communicate with external audiences or not. However, the cultural background of an audience, which is dependent on factors such as gender, race/ethnicity, social class and religion, has an influence on their attitudes toward science and how they may respond to scientists in the public arena (Kaslow, 2015). The question then arises whether scientists' own population group (or race/ethnicity) has an influence on how they experience interactions with external audiences, and whether it has a bearing on the perceived benefits and barriers associated with public engagement.

Given the history of racial inequality in South Africa, I had reason to believe that population group could have an effect on interactions between scientists and public audiences, and the associated attitudes and motivations of scientists to engage with the public. For example, depending on whether they are black or white, scientists may perceive different responses from audiences. This could also depend on the nature of the audience.

Furthermore, a scientist's population group may have an influence on her/his motivation to go public (for example, the desire to become a role model for other black scientists) or the associated objectives of public communication (for example, the goal of attracting more black youth to careers in science in order to diversify the science workforce). The literature confirms that scientists are motivated by the objective of inspiring young people in order to recruit future scientists (The Royal Society, 2006; Holliman & Jensen, 2009; Illingworth & Roop, 2015), and that some particularly try to attract under-represented groups (Martín-Sempere *et al*., 2008).

In his profile of Neil deGrasse Tyson, featuring him as one of the scientists that have achieved celebrity status in science, Fahy (2015) writes about the importance of role models in shattering stereotypes in science, and notes that black scientists, in particular, may be motivated towards public communication by a desire to help overcome racial stereotypes. Fahy (2015) relates how racial bias affected DeGrasse Tyson's career and how important, but challenging, it was for him to overcome the expectations of the media that black intellectuals should mainly address black issues. In his autobiography, DeGrasse Tyson recollects a significant moment while watching television late one evening (DeGrasse Tyson, 2004:136):

> On the screen before me was a scientific expert on the Sun whose knowledge was sought by the evening news. The expert on television happened to be black … At that moment, the entire fifty-year history of television programme flew past my view. At no place along that timeline could I recall a black person (who is neither an entertainer nor an athlete) being interviewed as an expert on something that had nothing whatever to do with being black.

These considerations are particularly pertinent in South Africa where encouraging black learners to consider careers in science is an important policy imperative, and the societal value and influence of black scientists in public life cannot be ignored. In order to increase the visibility of black scientists in South Africa, a new generation of black scientists must be equipped with the confidence and skills to become publicly visible via mass media platforms. Consequently, **population group** was included as a concept in my conceptual model guiding the study (see Figure 2.4), and was explored in the empirical component of this study.

3.3. Literature review: attitudinal factors

3.3.1. Norms

> ***The new visible scientists are often seen by their colleagues almost as a pollution in the scientific community – sometimes irritating, sometimes hazardous. The new scientists are breaking old rules of protocol in the scientific profession, questioning old ethics, defying the old standards of conduct.***
> *(Goodell, 1975:10)*

3.3.3.1. Defining and describing scientific norms

Scientists around the world share a common set of methods and they work according to a collective set of expectations (Anderson, Ronning, DeVries & Martinson, 2010). These scientific norms, or unwritten codes of conduct, are described by sociologist Robert Merton as a binding set of "prescriptions, proscriptions, preferences, and permissions" that shape the ethos and spirit of science (Merton, 1942:116). Goodell (1975:143) calls it a "powerful system of social control" that operates within science "to keep its members up to certain standards". Deviating from the desired behaviour may result in some kind of penalty (Rimal & Real, 2003) and the "moral indignation" of peers (Merton, 1942:117). Merton's classic norms (Merton, 1973), namely communism,[37] universalism,[38] disinterestedness[39] and organised scepticism,[40] are cultivated in young scientists (Goodell, 1975) and internalised by all scientists to varying degrees.

Science communication scholars have long been interested in how norms shape the way scientists communicate in public. In particular, they have studied how norms influence scientists' media interactions and academic reputations (Dunwoody & Ryan, 1985; Schneider, 1986; Mellor, 2010; Peters, 2013). Researchers are particularly interested in the motivations of scientists to comply with normative beliefs in order to conform to the expectations of others (Ajzen, 1991).

An example of a widely accepted norm in science is to delay public communication about a new study until it has been peer-reviewed and published (Gregory & Miller, 1998; Trench & Junker, 2001; Geller, Bernhardt, Gardner, Rodgers & Holtzman, 2005; Mellor, 2010). Scientists may therefore frown upon colleagues who present findings to the media prematurely, as was the case in the cold fusion saga (Lievrouw, 1990). Scientists also fear that they may lose their competitive edge if they speak out about their research too soon, as articulated by Mitroff (1974:593):

> Whatever the ultimate implications of the study, it has long been an unwritten rule of science that you don't divulge what you're up to until you're 99% sure that you've got the competition beat in the race to print.

Furthermore, Gregory (2009:5) sees the impersonal tone and passive voice used in scientific publication as a reflection of disinterestedness, and she describes the scale and scope of scientific publications and peer review as "a triumph of organized scepticism".

3.3.3.2. Intense peer scrutiny of highly visible scientists

Traditionally, the science community has not encouraged outward communication by its members, and has been known to penalise those who become highly visible in public (Gunter, Kinderlerer & Beyleveld, 1999). Consequently, it has been found that visible scientists are much discussed, but also "idolized, cursed, applauded and ridiculed" (Goodell, 1975:11), and that they "cause

[37] Communism: scientists should share their findings so that anyone can access and build on new knowledge, but the emphasis is on communication within science.

[38] Universalism: scientists work together as a tribe with a common goal of building a reliable body of knowledge. This is achieved by subjecting knowledge claims to impersonal criteria.

[39] Disinterestedness: science should not serve the interest of any specific individual or group, and scientists should not stand to gain any specific advantage from the knowledge they produce.

[40] Organised scepticism: new claims are subject to peer scrutiny before acceptance.

consternation among science-watchers and policy-makers", especially when they speak outside their areas of expertise, as they often do (Goodell, 1975:10).

While they may be concerned about peer pressure and criticism, negative comments do not necessarily deter scientists from media engagements (Poliakoff & Webb, 2007). Interestingly, Marcinkowski *et al*. (2104) suggest that scientists with very few media contacts themselves are probably the most critical.

Another normative concern about the way that science is featured in the mass media is that it bypasses peer review (Rödder, 2012). According to Shaw (2017), the hyper-critical attitude that characterises scientific culture originated from peer review, but has spilled over into public communication. Therefore, scientists who become visible in the public domain usually face conspicuous scrutiny from peers. Scientists are especially vulnerable when they try to make their work popular and media-friendly, for example by speaking about their work in less precise terms.

Furthermore, scientists who devote a significant portion of their time to public engagement may come under scrutiny from their colleagues for neglect of their academic obligations (MORI, 2001; Ren, Liu, Wang & Yin, 2014; TNS-BMRB, 2015). Goodell (1975) recounts how Paul Ehrlich, a Stanford-based lepidopterologist who became famous in the 1970s for his views about overpopulation, at one stage in his career worked 18 hours a day giving talks and doing interviews, while leaving his research largely in the hands of two capable graduate students. In Ehrlich's case, his colleagues supported his population cause, recognised his talent to popularise the issue and saw the value of his high public profile. Realising that the media demanded Ehrlich and no one else, they pulled together behind the scenes to sustain his public visibility.

3.3.3.3. The scientific cost of public visibility

The case of Carl Sagan is frequently cited as an example of how scientific norms affect a scientist's career. In 1992, Sagan's nomination to the (United States) National Academy of Sciences was voted down. At the time, he was a leading planetary scientist, but also a well-known science populariser.[41] It is widely believed that the science community did not approve of his media visibility (Nisbet, Scheufele, Shanahan, Moy, Brossard & Lewenstein, 2002; Sturzenegger-Varvayanis, Eosco, Ball, Lee, Halpern & Lewenstein, 2008; Shugart & Racaniello, 2015). Subsequently, scientists' fears that public visibility could penalise them career-wise became known as the 'Sagan effect' (Gwynne, 1997; Dean, 2009; Ecklund *et al.*, 2012; Dudo, 2013; Martinez-Conde, 2016). Notably, Johnson, Franklin, Cottingham and Hopwood (2010:14) provide a recent example of a funding application that was refused, in part because the reviewers "were antagonized by the applicants' high media profile".

[41] Sagan wrote several award-winning books, but became especially well known for *Cosmos,* a 13-part television series first broadcast in 1980, and subsequently seen by hundreds of millions of people (Lessl, 1985). Science writer Stuart Baur describes Sagan as "that rarest of creatures – an effective media-scientist" (Baur, 1977, quoted in Goodell, 1977:171).

An earlier example of a scientist who was scorned by his peers when he became famous is Jonas Salk who discovered a polio vaccine in 1955. He became a public hero overnight and he was publicly praised by President Dwight Eisenhower.

In her biography of Salk, DeCroes Jacobs (2015) contrasts this public acclaim with the professional disdain that erupted, claiming that fellow scientists were resentful and jealous and felt that Salk achieved media fame before paying his scientific dues. Despite his efforts, Salk never fully regained the respect of many of his fellow scientists.

Like Sagan and Salk, many high-profile scientists have, on occasion, experienced damaging criticism from peers that may have resulted from professional jealousy. For example, Hillis (quoted in Brockman, 1996:26), says:

> When you get somebody who's very articulate, like Gould or Dawkins, other scientists get a little bit jealous, because those two are explaining to the public the issues we're arguing about.

In South African medical history, the heart transplant pioneer, Christiaan Barnard, endured the disdain of his peers (Nathoo, 2009). However, described as an outspoken advocate for boldness and heroics in medical practice (Cooper & Cooley, 2001), Barnard was also perceived as someone determined to withstand peer criticism.

The scientific establishment seems to be particularly disapproving of public events that are specifically orchestrated to showcase scientific advances to large audiences and to attract maximum media attention. For example, when Brazilian neuroscientist Miguel Nicolelis and his colleagues at Duke University used the opening ceremony of the 2014 Football World Cup to demonstrate their mind-controlled exoskeleton to global audiences, they faced widespread peer criticism (Aldern, 2014). Their so-called 'walk-again machine' allowed 29-year-old paraplegic Juliano Pinto to kick off this major soccer event symbolically (Martins & Rincon, 2014). Scientists questioned whether the technology was ready to be revealed to the world, arguing that it promised too much too soon, and accused Nicolelis of attempting a publicity stunt. Similarly, when palaeontologist Lee Berger invited journalists from around the world to the Cradle of Humankind in South Africa in late 2015 for the announcement of the discovery of a new hominid species, *Homo naledi,* he was accused of doing his research under the glare of National Geographic cameras, rushing things to suit filmmakers and turning the announcement into a media circus (McKie, 2015).

While scientists with a strong track record may be able to weather the storms that could result from publicity (Dunwoody *et al*., 2009), Goodell (1975) believes that status does not shield scientists from contempt. Visible scientists are not oblivious to attacks on their credibility, and often cringe when criticised by peers.

3.3.3.4. Normative reforms regarding public science communication

Searle (2011) argues that the rules (or norms) of the science community that used to govern public communication were designed to protect and enhance the reputation and authority of science and scientists, and not to serve the public. Consequently, these rules have constrained scientists' efforts at public communication and contributed to the image of scientists as poor communicators. In response to a growing awareness of the need to bolster public support for science, the science community is modifying its rules and increasingly approves of scientists' participation in public life (Searle, 2011, 2013; Rödder, 2012). These changes in the normative structure of science are indicative of the changing interfaces between science and other spheres of society, such as politics and mass media, as observed over recent decades.

Instead of snubbing public communication, science leaders increasingly call on scientists to communicate more forcefully and strategically with public and policy audiences. Scientific leaders create incentives to support the involvement of the scientists (Bodmer, 1985; Lubchenco, 1998; Durant, 1999; Leshner, 2003; Baron, 2010b). In Sweden, for example, institutional attitudes regarding public communication has changed drastically from deeply sceptical to enthusiastically supportive, mostly in response to increased competition for resources. University leaders have started to encourage researchers to help cultivate a favourable public image for science (Engwall, 2008).

As a result, scientists are less concerned about negative reactions from peers, and norms become less restrictive when scientists engage with external audiences and the mass media (Peters *et al*., 2008a; Marcinkowski *et al*., 2014). Peters (2013) goes further by suggesting that media interactions have become normalised as part of being a scientist, particularly for scientists in leadership roles. Consequently, the science community is becoming more tolerant of media visibility, and is beginning to recognise it as an indicator of broader, societal impact.

Views about the acceptability of communicating with external audiences as a means to attract funding may also be changing. In the past, scientists did not regard seeking publicity for monetary gain as a respectable endeavour (DiBella, Ferri & Padderud, 1991). More recently, scientists started admitting freely that they are motivated by the prospect of money to work with the media, and they are particularly keen to impress research sponsors via media visibility (Peters *et al*., 2008a; Allgaier *et al*., 2013a; Marcinkowski *et al*., 2014). Not surprisingly, the idea that scientists are motivated towards public communication by the prospect of money continues to meet with criticism. A key concern is that scientists may care more about the potential of media exposure to attract funding than about the accuracy of the media coverage (Koh *et al.*, 2016). Ongoing changes in the science communication landscape, in particular the disintegration of traditional media coupled with the rise of science PR and social media, are fuelling criticism of scientists who are engaging more frequently and more directly with public and policy audiences to gain attention and funding for themselves and their institutions (Weingart & Guenther, 2016).

Despite agreement that, as far as public communication is concerned, norms in science have moved on from "shun the limelight" to "thou shalt communicate", Rödder (2012:157) admits that scientists willing to engage in raising the public visibility of their universities may still find that it could tarnish their scientific reputations. Consequently, some scientists remain concerned that a high media profile could compromise their scientific standing (The Royal Society, 2006).

3.3.3.5. Rules and strategies for public science communication

The science community may accept and support the public visibility of scientists, as long as certain rules are not broken and specific conditions are met (Rödder, 2012; Peters, 2013).

The conditions that make public communication normatively acceptable have been described by, amongst others, Goodell (1977), as well as Gregory and Miller (1998). These rules include:

- Visible scientists should have a strong track record and a solid reputation.
- Scientists should postpone most public efforts until later in their careers when they have concluded the bulk of their research outputs.
- Public communication should focus on scientific content and avoid self-promotion.
- Scientists should restrict public communication to their specific areas of expertise.
- Scientists should limit their media interactions to reputable news organisations.
- Public communication should not take up more than a small percentage of a scientist's time.
- Scientist should confine their public remarks and activities to those that extol the virtues of science, and avoid controversies that could harm the public image of science or scientists.
- Political views expressed in public should be moderate and political activities are only acceptable if they enhance the scientific establishment.

Reflecting on these rules in the current science communication climate, some are clearly no longer in line with current views on who should be communicating and how the communication should be done. Rödder (2012:160) notes that when scientists feature in the mass media, they cannot shield themselves from being seen by their colleagues and it is inevitable that they will be concerned over their colleagues' impressions. Therefore, scientists try to increase the legitimacy and acceptability of public visibility within the normative structure of science in one or more of the following ways:

- They ground their media prominence in sound science and professional merit.
- They link their public visibility to their institutional leadership role.
- They wait for the media to come to them, since media visibility seems to be more acceptable when initiated by journalists, rather than pro-active efforts by scientists.

3.3.2. Attitudes towards the public

> ***Like some editors and television producers, some scientists believe the public is too ignorant or too stupid to understand science, that the enterprise of popularization is fundamentally a lost cause, or even that it's tantamount to fraternization, if not outright cohabitation, with the enemy. Among the many criticisms that could be made of this judgement – along with its insufferable arrogance and its neglect of a host of examples of highly successful science popularizations – is that it is self-confirming. And also, for the scientists involved, self-defeating.***
> *(Sagan, 1996:334)*

The way scientists see the public influences their attitudes about the need to engage public audiences. When scientists are positive about the public, seeing them as interested and able to engage, the scientists are more likely to be involved in reaching out to public audiences than scientists who have a negative view of the public. Hence, scholars have sought to understand the relationships between scientists and their publics, i.e. scientists' attitudes toward the public, and public attitudes toward science (Stilgoe & Wilsdon, 2009; Davies, 2013a).

In order to engage successfully with the public, it is necessary for scientists to understand the nature and information needs of public audiences (Mooney, 2010). Already in 1941, Sir William Henry Bragg, then president of The Royal Society of London, instructed scientists to "understand more about the people that they met if they wanted the best chance of bringing about the changes scientists desired" (Bragg, 1941:27). Lewenstein (1992a:xv) articulates the need to understand and respect the intended audience in public communication of science as follows:

> One must go where the audiences are, speak their languages, and understand their vision of science if one is ever to be successful at engaging the broad public into the enterprise of science.

3.3.2.1. Acknowledging public diversity

Irwin and Horst (2016) warn against the conflation of different publics into a generic whole. Scientists need to consider diverse constituents, including "the informed, educated, interested and engaged populations, as well as naive, uninterested and poorly educated groups" (Turney, 2006:38). As pointed out by Bucchi and Trench (2014:6), the use of the plural form 'publics' (a commonly used term when discussing science in society) is already "an indication in shorthand that the public is diverse, even fragmented". However, some scientists continue to view the public as a homogenous entity, and remain unaware of the need to segment audiences and adapt to the needs of their audiences (Casini & Neresini, 2012).

In addition to its diversity, a nuanced view of the public demands a realisation that the public is not a passive participant in science, but rather "active, knowledgeable, playing multiple roles, receiving as well as shaping science" (Einsiedel, 2007:5). Einsiedel warns that it is ill-advised to ridicule the public for perceived ignorance and a lack of interest, but equally unwise to romanticise the public as dynamic, fair and eager to participate in science.

3.3.2.2. Scientists' views of the public

Surveys of how scientists view the public usually reveal a bleak picture. Scientists perceive the public as critical, risk-focused, uninformed and disinterested (MORI, 2001; Vetenskap & Allmänhet, 2003; Mathews *et al.*, 2005; Horst, 2013; Braun, Starkbaum & Dabrock, 2015). On top of this, some scientists perceive the public as ignorant and prejudiced (Agnella, De Bortoli, Scamuzzi, Cerbara, Valente & Avveduto, 2012) and even as misguided and irrational (Dudo & Besley, 2016). Additionally, scientists describe the public as emotional, prone to fear and overly focused on the sensational, with a tendency to rely on anecdotes (Besley & Nisbet, 2013). Generally, scientists believe that the public, except for a small minority, is uninformed about science and not interested in knowing more. Moreover, scientists believe that the public views scientists largely negatively, i.e. as detached, secretive and bad at communication (MORI, 2001), and that the public does not care about the work scientists do (Gascoigne & Metcalfe, 1997).

A few recent studies present a more optimistic picture of how scientists view the public, seeing them as intelligent, supportive and scientifically capable, and consequently scientists feel hopeful about public support for science (Burchell *et al.*, 2009; Pew Research Center, 2015b).

A negative view of the public may deter scientists' willingness to engage with external audiences (BBSRC, 2014; Johnson *et al*., 2014). Equally, scientists may refrain from public communication if they think that the public will not understand what their research is about (Kreimer *et al*., 2011; Mizumachi *et al*., 2011; BBSRC, 2014).

On the other hand, a perception that the public is largely uneducated may compel scientists to try and remedy the situation and motivate scientists to get involved in science outreach (Besley *et al.*, 2013). However, scientists who want to educate their audiences are likely to focus on giving out information, rather than dialogue (The Royal Society, 2006), leading to a persistent deficit approach to public science communication. Despite an abundance of recommendations and policies in favour of public dialogue, many scientists continue to view their own knowledge as superior. Therefore, they use one-way, top-down communication when they interact with the public (Davies, 2008; Braun *et al*., 2015; Casini & Neresini, 2012; Grand *et al*., 2015). Furthermore, scientists assign themselves a prominent role relative to society and disregard opportunities to learn from the public. As stated by Casini and Neresini (2012:56), scientists believe "it is their responsibility to take the initiative, it is they who have something to offer (scientific knowledge), and others have to change".

Moving away from deficit-style communication to a dialogue style and contextual approach requires of scientists to work with the public on an equal footing (Bakuwa, 2015). But, many scientists find this challenging, since it requires reciprocity and mutuality, as well as giving up a degree of control and accepting shared ownership of the research. This is "unfamiliar to many faculty and their disciplinary traditions" (Holland, 1999:66). Researchers may find it hard to accept that the public is able to make useful contributions to science discussions and policy decisions, and even harder to relinquish some of their hard-earned authority (Grand *et al*., 2015). The scientists are concerned about lay persons' knowledge of science and sceptical about their ability to make sound judgements about complex issues (Besley & Nisbet, 2013). As a result, many scientists are not convinced of the benefits or practicality of including inputs from non-experts into the governance of science, while even those scientists who acknowledge the need for public involvement in science, battle to put it into practice (Peters, 2013; Braun *et al*., 2015).

Some scientists are outspokenly opposed to public participation in science. For example, in a highly critical view of the drive to include non-scientists in science policy making, Durodié (2003:89) concludes, "We should not include 'lay values' or 'local knowledge' into science, peer review or anywhere else, as there is no such thing."

Another risk associated with scientists' negative views of the public is that it could result in counter-productive public–science encounters, including a patronising communication style and a lack of respect for the audience (Besley, 2015b; Dudo & Besley, 2016).

3.3.2.3. The public's view of science

The concern of the science society about what the public thinks of and knows about science is reflected in the abundance of regional, national and cross-country surveys of public opinion and knowledge fielded in the United States, Europe and many other countries, including South Africa. Examples of these surveys include the annual Science Indicators Surveys of the NSF that have been conducted since 1970, and the Eurobarometer surveys since the late 1980s (Bauer, 2008a; Hansen, 2009). In South Africa, such surveys are performed by the Human Sciences Research Council (HSRC) (Reddy *et al.*, 2013). A project called 'Mapping the Cultural Authority of Science" (MACAS[42]) compares findings and maps global trends in this field of research.

Surveys of the public repeatedly show that the public is largely uninformed about science, but interested to know more (Hively, 1988; Durant, Evans & Thomas, 1989; Miller, 1998; Bauer, 2009; Reddy *et al.*, 2013). Low levels of public science literacy are often seen as the cause of growing scepticism about science (Hansen, 2009), but Shortland and Gregory (1992) argue that there is nothing unusual about low levels of public knowledge about science. After all, people are similarly ignorant about politics and literature. This begs the question whether science, in particular natural sciences, deserves special treatment as far as public education and attention is concerned.

3.3.2.4. Why scientists care what the public thinks of science

Durant *et al*. (1989:11) put forward four reasons why public understanding of science matters.

> First, science is arguably the greatest achievement of our culture, and people deserve to know about it; second, science affects everyone's lives, and people need to know about it; third, many public policy decisions involve science, and these can only be genuinely democratic if they arise out of informed public debate; and fourth, science is publicly supported, and such support is (or at least ought to be) based on at least a minimal level of public knowledge.

There is ample evidence that scientists do care about the public view of science, but also that their concerns are largely driven by self-serving motives, such as concern over science funding and fears of anti-science sentiments that may limit freedom in scientific research (Ecklund *et al*., 2012; Besley, 2015a,b; Braun *et al*., 2015; TNS-BMRB, 2015). Consequently, many scientists desire to improve the public image of science (Nelkin, 1994; Hughes, 2001), especially when they perceive dwindling political and public support (McCall, 1988). Gregory (2001) agrees that popularisation efforts often come from scientists who rush to communicate with the public at times when they feel that their own enterprise is under threat.

Scientists have long believed that public communication efforts are needed to secure public support for science. For example, Goodell (1977:90) writes:

> Without public goodwill, research freedom and funding are in jeopardy. The scientific community is a morass of conflicting and changing attitudes on the subject of communicating with society, but it is fairly well accepted today that scientists must do some public relations work, some popularising,

[42] See http://www.macas-project.com/

> in order to loosen the public purse strings. This view increases as funds decrease and fears of anti-science sentiment grow. Scientists, previously afraid they would be misunderstood if they were involved with popular communication, now find they are misunderstood because they are not.

Along similar lines, Gastel (1983:ix) claims, "helping the public to understand science is likely to foster public support", and scientists are cautioned that it would be "unwise to presume upon the continued backing of a public that knows little of what scientists do" (Durant *et al.*, 1989). As such, the objective of gaining support is a major motivator of scientists' efforts to communicate their work in public (Greenwood & Riordian, 2001).

3.3.2.5. The relationship between knowledge and support

While the motive to increase public acceptance of and support for science is not the only driver of public communication, scientists certainly hope and expect that their outreach efforts will translate into acceptance and ultimately more generous budgets for research. The need to secure public support for science remains a strong motivation for calling on scientists to reach out to the public. In his address at the 1999 UNESCO World Conference on Science, Mayor (1999:26) said:

> Direct public support is the lifeblood of basic research and of all levels of science education. Make no mistake: science needs political will. In return for funding and structured support, science must respond to the needs of society.

However, social science research reveals that public communication of science does not necessarily result in more public support for science (Gregory, 2001). As pointed out by Cheng *et al*. (2008:2), "the reality is much more complex". In fact, scientific literacy and scientific ideology are negatively correlated in most countries, meaning that more knowledgeable citizens are more likely to reject new scientific ideas (Bauer, 2008). In other words, "the more we know the science, the less we love it" may be closer to the truth (Bauer, 2008b:21). Therefore, the author argues, a more desirable state of affairs in a modern knowledge society is to aim for the co-existence of scientific productivity and a critical public with a healthy scepticism about science.

Weingart (2002) points to another reason why public communication to secure support for science may backfire. The author highlights intensified competition for funding as one of the reasons why scientists are increasingly turning to the public and seeking media coverage for their work. He cites climate change as a prime example of how scientists' dire warnings of catastrophe and disaster, but also the promise of solutions, have resulted in funding of their work. However, Weingart (2002:705–706) then warns:

> The strategy of using the media to generate public support for research is surely doomed to fail. Instead, it strengthens the suspicion that scientists have their own agenda and further endangers their public credibility.

Currently, ongoing contentious developments in science and advanced technologies continue to pose thorny communication challenges (Priest, 2006; Nisbet & Scheufele, 2009; Scheufele, 2013). Nanotechnology is an example of a so-called 'wicked problem': an issue with social, ethical and legal implications, characterised by high policy stakes and a high degree of uncertainty (Conklin, 2005).

Another innovation that is attracting societal debate because of its inherent promise (but also perceived risk) is a potentially revolutionary gene-editing technique called CRISPR (i.e. clustered regularly interspaced short palindromic repeats) (Pennisi, 2013). Debates about these emerging technologies are often moral, philosophical and political rather than academic (Sarewitz, 2015). As a result, "public communication about modern science is inherently political, whether we like it or not" (Scheufele, 2014:13586).

However, even if public science communication is by no means a guarantee of public support, many arguments in favour of closer interaction between scientists and public audiences remain valid. For example, Cheng *et al*. (2008:3) argue that, even if popularisation of science fails, public science engagement brings science into a cultural and democratic debate, and this would constitute success in terms of the socialisation of science. As such, Cheng *et al.* (2008) contend that public science communication is necessary in order to reintegrate science within culture. Similarly, Mathews *et al*. (2005) say that science is embedded within, and dependent on, larger cultural and political constituencies and can, therefore, only thrive if it partners with policymakers, ethicists, the media and the public who funds the research and must ultimately live with its results.

3.3.2.6. Public trust in science

Increasingly, nurturing public trust in science is recognised as a more meaningful objective than increasing public knowledge about science (Wynne, 2006; Gauchat, 2011; Resnik, 2011; Fiske & Dupree, 2014). Weingart (2002) agrees that public trust in science is invaluable, and that the science community should do what it can to preserve it.

The 1996 BSE crisis resulted in an unprecedented breakdown of trust between the public and government scientists in the United Kingdom (Jasanoff, 1997; Irwin, 2009) and its effects reverberated around the globe (Pitrelli, 2003). A parliamentary committee investigated the perceived crisis of confidence in science and produced a report (House of Lords, 2000) that acknowledged the right of the public to question scientific authority, and accentuated the value of direct, open and timely dialogue with the public. This report signalled a growing awareness that public opinion of science has to be taken seriously. Subsequently, scientists became increasingly aware that scientific issues are subject to public debate and scrutiny, while the public also has a role to play in science practice and policy (Young & Matthews, 2007; Braun *et al.*, 2015). Today, most scientists accept the need to engage with public pressure and lobby groups, particularly to discuss emerging (and potentially contentious) research topics (Burchell *et al.*, 2009; Porter *et al.*, 2012).

3.3.3. Attitudes towards public communication

> ***Without an informed public, scientists will not only be no longer supported financially, they will be actively persecuted.***
> *(Asimov, 1983:119)*

The professional stigma that seems to be attached to science popularisation, at least in some circles, dates back to the late 19th century, around the time when science became professionalised (Bowler, 2009). Wells (1894:300) writes in *Nature* about the vital need to popularise science, despite "a certain flavour of contempt" associated with popular science. According to Gwynne (1997), young scientists who want to engage with public audiences face a serious dilemma since those who succeed at popular communication may be regarded as lightweight scientists by their peers. Likewise, Whitley (1985) states that popularisation is typically regarded as a low-status activity, unrelated to research work, which scientists are often unwilling to do and for which they are ill-equipped. Shortland and Gregory (1992:5–6) agree that some scientists still look down on colleagues who communicate their work externally, adding that serious scientists are not expected to have the time or inclination "to blow their own trumpets". The authors add:

> So, there are problems with communicating science: the pessimists' worst possible case is that your colleagues will never speak to you again, your reputation as a serious scientist will end up in tatters and the source of your research funding will one day mysteriously run dry. That's a high price to pay, especially when you can never be quite sure what the public will make of it all.

"It's true that 'popularizer' is a pejorative term among scientists generally," writes Hillis (quoted in Brockman 1996:26):

> A popularizer is somebody who explains what the issues are in ways that people can understand. I think it's ridiculous that scientists don't respect such people. In any other field, explaining to a congressional committee why what you're doing is exciting and wonderful would be considered a service to the field. In science, you're treated almost like somebody who has betrayed the secret club.

Furthermore, scientists' views of public communication (as a core or peripheral activity in their professional lives) influence their evaluation of this role as an essential versus optional activity and will therefore determine their attitude towards public science communication. While scientists may increasingly recognise the value of public engagement (on a personal and career level) it remains a low-priority activity for many. In other words, it is important, but not as important as other tasks. For example, Checkoway (2001) maintains that university-based scientists see themselves as researchers and teachers first and foremost, and therefore do not regard public communication as central to their roles. Essentially, popularisation is relegated to an activity outside the core process of science, a task that can be left to non-scientists, failed scientists or ex-scientists. Checkoway agrees, however, that scientists who wish to focus attention on their research, attract significant funding or gain political support for a particular position in a scientific controversy, have to re-think this attitude towards popularisation.

Research findings more or less consistently reveal that most scientists do not view communication outside the academic environment as a core part of their work, but rather as an altruistic activity (Gascoigne & Metcalfe, 1997; The Royal Society, 2006), a form of volunteer work (Andrews *et al*., 2005), or a personal choice (Horst, 2013). France *et al*. (2015) argue that this view of public engagement, as peripheral to the role of a scientist, leads to an ongoing tension for scientists who decide to engage with the public about their research.

A UK survey commissioned by the Wellcome Trust to examine trends in public science engagement since 2006 (TNS-BRMB, 2015), detected a positive shift in the number of researchers who regarded public engagement as a core component of their role, rising from 28% in 2006 to 37% in 2015. McCann *et al*. (2015) report a similar shift amongst US scientists.

The diversity of scientists' attitudes towards public communication is evident in research by Jensen (2011) and Marcinkowski *et al*. (2014), which led them to suggest that scientists can be classified in three engagement types: inactive, open, and always active. The 'inactive' scientists are not concerned by outreach and never become involved. Those in the 'open' category participate occasionally, while the 'always active' scientists display ongoing commitment to public engagement. Similarly, Bucchi and Saracino (2012) propose that scientists could be labelled with one of the following five engagement attitudes: (1) It is important to communicate, provided I am not in charge, (2) Let us discuss it, (3) Let me explain it in my own terms, (4) Oh, no, I have to communicate!, and (5) Leave me alone, I have to work!

Several studies specifically asked scientists how they experienced the benefits and drawbacks of public communication. There is ample evidence that scientists experience both positive and negative effects, and therefore they respond differently to communication opportunities. In some recent studies, the bulk of scientists who responded were positive about public engagement and media interactions, saying, "the benefits outweigh potential negative effects" (Allgaier *et al*., 2013b:426) and that they experienced favourable influences on their careers and scientific reputations (e.g. Peters, 2013; Dudo *et al*., 2014; Wien, 2014; Koh *et al*., 2016; Massarani & Peters, 2016). Increasingly, therefore, scientists concur that participation in policy debates and engagement with citizens and journalists are necessary and beneficial components of a scientific career (Pew Research Center, 2015). Therefore, scientists seek out engagement opportunities pro-actively and strategically, instead of waiting for journalists to approach them (Peters, 2012).

If frequency of involvement is taken as an indicator of scientists' attitude towards public engagement, there is even more reason to believe that scientists are generally positive about these activities. Several recent surveys have shown that, depending on how public engagement is defined, the majority of scientists are involved in one way or another. When a whole range of activities were included (public speaking, popular writing, media interviews, open door events, social media, etc.), between 30 and 90% of scientists said that they were involved (The Royal Society, 2006; Abreu, Grinevich, Hughes & Kitson, 2009; Burchell *et al*., 2009; Kreimer *et al*., 2011; Crettaz Von Roten, 2011; TNS-BMRB, 2015).

3.3.3.1. The influence of scientists' communication objectives

An individual's motivation to do something depends, to some degree, on her/his underlying objectives (Ryan & Deci, 2000). As such, an individual scientist's communication goals drive her/his attitude towards public communication, and consequently the associated behaviour. That means that it is critical to understand what scientists hope to achieve with their public communication efforts (Dudo & Besley, 2016).

When asking scientists about their communication goals, researchers receive a range of answers that include helping others, helping their organisations and helping themselves. For example, Davies (2008) describes three main public science communication objectives held by scientists, namely helping to promote scientific literacy, recruiting future scientists, and arousing interest in scientific research. Goodell's (1975) visible scientists were seeking to influence people and policies. Scientists are keen to demonstrate public accountability, influence policymakers, raise the profile of science, drive social change, and increase the relevance of their work (Braun *et al*., 2015; Grand *et al*., 2015). Dudo and Besley (2016) report that scientists are most interested in defending science from misinformation and educating public audiences. Large-scale US and UK studies concur that scientists are motivated towards public engagement by personal benefit, looking to advance their own careers, increasing appreciation of their work and contributing to their visibility and funding (Pew Research Center, 2015; TNS-BMRB, 2015).

Some scientists are direct about the need to keep the public, who pays for much of research, satisfied. Tim Vogels, a computational and theoretical neuroscientist at the University of Oxford (quoted in Aldern, 2014) says, "If we want to keep getting money, we have to engage the public. The public is paying for us—it's our boss."

Some scientists have cultural objectives in mind when they go out to meet the public. For example, scientists who take part in science fairs want to go beyond communicating knowledge. They try to stimulate interest and enhance scientific culture and enthusiasm for science (Martín-Sempere *et al*., 2008).

A specific line of enquiry, particularly prevalent in studies performed towards the end of the 20th century, has been to examine scientists' objectives in terms of working with journalists (Dunwoody & Scott, 1982; Kirsch, 1982; DiBella *et al.*, 1991; Dunwoody *et al.*, 2009). Kirsch suggests that scientists assume different roles when they become sources for the mass media, namely:

- the political or social activist, seeking to influence public opinion;
- the science populariser, hoping to enhance public interest in science;
- the commercialiser, looking for applications and collaborators in industry;
- the advisor, offering advice to policymakers and the public; and
- the science manager, in the role of organisational spokesperson.

3.3.4. Attitudes towards mainstream media

> ***Newspapermen and scientists are both in pursuit of the truth. That's about all they have in common. Scientists tend to be very serious about trivial things. Journalists are often trivial about very serious things. It may not be possible to square this circle.***
> *(Radford, 1997:39)*

The potential for mutual benefit in collaboration between scientists and journalists, and the role of the media in creating linkages between science and society, have long been recognised (Tsfati *et al*., 2011; Dudo, 2015), also in African societies (Lugalambi, Nyabuga & Wamala, 2011; Appiah *et al.*, 2015). Since the second half of the 20th century, specialist science reporters played a pivotal role in making scientific advances visible to the general public (Swinehart & McLeod, 1960; Dunwoody, 1980; Kirsch, 1982; Nelkin, 1995).

The influential role of the media was (and still is) widely recognised and journalists became brokers who shaped public attitudes about science. Nelkin (1995:2) explains the influential role of the media as follows:

> For most people, the reality of science is what they read in the press. They understand science less through direct experience or past education than through the filter of journalistic language and imagery. The media are their only contact with what is going on in rapidly changing scientific and technological fields, as well as a major source of information about the implications of these changes for their lives.

The term 'scientization' of the mass media was coined to reflect the increase in science press coverage (Hansen, 2009), a model largely based on an unbroken faith in scientific progress (Maeseele, 2007). Scientists became increasingly aware of the media as a powerful ally in spreading their ideas and gaining public support (Nelkin, 1995). This resulted in a strategic shift amongst scientists (driven by funding, legitimacy and ethical concerns) to seek media attention (Hargreaves & Ferguson, 2000; Albaek *et al.*, 2003; Bauer & Gregory, 2007).

Today, editorial and financial pressures, coupled with changes in the media landscape, are changing the mass media profoundly. The role of journalists, once revered as independent gatekeepers of scientific information, has been significantly eroded by the rise of online media and the pervasiveness of social media (Brumfiel, 2009; Brossard & Scheufele, 2013; Dudo, 2015). By presenting media-attractive science content, institutional communicators are making it easier for journalists to report on science than before (Peters *et al.,* 2008b). This comes with the risk that journalists may be tempted to sensationalise science and re-hash institutional PR materials uncritically (Weingart & Guenther, 2016).

3.3.4.1. Conflicts between scientists and journalists

The traditional view of scientists and journalists is that they do not get along, and that – when they do meet – "the encounters are tense" (Dunwoody & Scott, 1982). Conflicting professional norms and dissimilar cultural values are believed to be at the root of this problematic relationship (Gregory

& Miller, 1998; Reed, 2001; Weigold, 2001; Kennamer, 2005). Therefore, for the relationship to improve, both scientists and journalists would have to make an effort to understand the "purposes, values, and procedures of the other" (McCall, 1988:87).

Divergent communication styles, time frames and language use are examples of the differences in the professional cultures of science and journalism (Nelkin, 1995). For scientists, new information is the result of long-term and intensive research, while journalists regard news as something that is current and of immediate interest. Scientists prefer a serious, fact-based style of communication, using complex and cautious language, with a long-term focus. Journalists prefer clear and simple messages (Peters, 2014), simple answers to current problems (Metcalfe & Gascoigne, 2009) and exciting stories in an entertaining and emotive style (Olson, 2010; 2013; 2015). Scientists feel that journalists do not understand the nature and culture of science and therefore try to explain science and the scientific method, while journalists want to write about short-term results and their immediate implications (Claessens, 2008).

Scientists and journalists may also disagree on what constitutes news (Fahnestock, 1986). When scientists try to get media attention, journalists are not necessarily interested in what is presented to them and may therefore try to find a different angle on the story (Tsfati *et al*., 2011). Weingart (2002:705) notes that journalists "create their own reality" and select stories according to criteria such as "actuality, sensation, personalities and local implications". These are so far from the criteria that guide scientific communication that Weingart believes complaints about distorted media coverage of science are displaced, adding, "there can be no 'adequate' presentation of science in the media in a way that satisfies scientists".

Contradictory expectations about the roles of scientists and journalists also cause tensions to soar when these professions interact. Many scientists expect journalists to promote science and may view journalists, naively, "as mere instruments of transmission" (Casini & Neresini, 2012:57) to the extent that scientists may feel betrayed when their views are challenged (Nelkin, 1995). By contrast, well-trained journalists see themselves as societal watchdogs with a duty to serve the interests of their readers (Wilcox, 2003; Lynch & Condit, 2006; Allan, 2009) and may therefore legitimately choose a critical approach (Dunwoody, 2004; Fahy & Nisbet, 2011). After all, it is not the job of the media to promote science or the public understanding of science (Treise & Weigold, 2002).

The question of control over the final version of a media story is a persistent source of tension between scientists and journalists (Gunter *et al*., 1999; Peters, 2014). Most journalists reject the idea that they should consult the scientists they have interviewed before a story goes to print, while scientists typically support this notion (Massarani & Peters, 2016). Journalists see themselves as the authors and owners of the story, and ultimately responsible for deciding the angle and content of the story. Their only obligation to the scientists, as sources, is to treat them fairly by quoting them correctly. Scientists, on the other hand, argue that the story is based on their work and that their reputations are on the line.

While the importance of critical and investigative science journalism cannot be denied, science journalists are usually less critical than, for example, political reporters, with the result that the bulk of media coverage of science is largely positive (Peters *et al.*, 2008a). Nelkin (1995) consequently contends that many reporters are retailing science, rather investigating it, and are identifying with their sources, rather than challenging them. This kind of science reporting does not help people to make informed choices about new developments in science, Nelkin adds. For that, probing, investigative journalism is required, as well as scientists who respect critical enquiry on the part of journalists.

Hilgartner (1990) suggests another reason why scientists occasionally adopt a critical stance towards the media. From time to time, it suits scientists to differentiate scientific knowledge from popular knowledge and to frame the popularisation of science as a flawed process that distorts science, thereby reinforcing the social hierarchy of expertise. In this hierarchy, "genuine scientific knowledge" is positioned as the "gold standard" and the "exclusive preserve of scientists", while policymakers and the public "can only grasp simplified representations" (Hilgartner, 1990:520). This allows scientists, depending on what best suits their purpose, the authority to determine when simplifications are deemed appropriate and useful (on the one hand) or useless distortions (on the other).

It is also worth keeping in mind the differences in the obligations towards collaboration between scientists and journalists. While it is the journalist's job to interact with sources (including scientists), it is not the scientist's core task to work with journalists (Dijkstra *et al*., 2015). Consequently, some scientists question whether these interactions are worth the effort. Furthermore, scientists' strong belief that journalists should only report on research that has been peer-reviewed could also give rise to frustrations and clashes (Massarani & Peters, 2016).

In addition to the potential problems discussed above, intense competition between media outlets and the explosive growth in the number of media channels, means that there are no longer captive audiences for science information (Borchelt, 2001). At the same time the number of specialist science writers continue to decline (De Semir, 2010). Consequently, pitching a science news story successfully to the mass media requires expert knowledge, popular science writing skills, and the ability to select and target appropriate media outlets (Harcup & O'Neill, 2016). Researchers are often ill-prepared to play by the contemporary media rules (Nelkin, 1995; Russell, 2010).

Being pragmatic about their own communication objectives, some scientists are willing to adapt to media logic and journalists' needs (Peters *et al*., 2008b). However, Massarani and Peters (2016:7) demonstrate a limited willingness on the part of scientists to adapt the way they speak about their work, stating that while "using catchy phrases that can be quoted verbatim by reporters" may get attention, this is not seen as appropriate from scientists' perspectives.

Notably, high-profile scientists are typically acutely aware of the power of the media and keen to use it for gaining visibility and influence. As Paul Ehrlich (quoted in Goodell, 1975:20) asserts, "[a]ny loudmouth, if instead of talking to 200 students at a time, can talk to 200 000 over radio and TV, is obviously going to take the opportunity."

At the turn of the century, a milestone report from the UK Parliament (House of Lords, 2000) concluded that there was no basis for scientists' long-standing complaints about dangerous inaccuracies in science media coverage. The authors reprimanded scientists for expecting special treatment from journalists and urged them to intensify media collaborations. Other authors have agreed that scientists' lack of understanding of mass media practice leads to misunderstandings (Gascoigne & Metcalfe, 1979; Borchelt, 2001; Gregory, 2001). They point out that a working knowledge of the media would facilitate constructive collaboration (McBride *et al*., 2007).

3.3.4.2. Relationships between scientists and journalists

Historically, science–media relationships have been problematic. The relationships are characterised by feelings of ambivalence, mistrust and even contempt (Dunwoody, 1982; Gregory & Miller, 1998; Gunter *et al*., 1999; Ruth *et al*., 2005; Dunwoody *et al*., 2009; Metcalfe & Gascoigne, 2009; Claassen, 2011; Corley *et al*., 2011; Porter *et al*., 2012; Smith, Baron, English, Galindo, Goldman, McLeod, Miner & Neeley, 2013; Dijkstra et al., 2015). Dunwoody *et al*. (2009:300) state, "[b]oth science and journalism reflect – with a mixture of regret and bemusement – on a historically thorny relationship."

Scientists' concerns over the quality of media coverage of science peaked after WWII (Dornan, 1990). Krieghbaum (1968) complains that the media either ignored or sensationalised science, and calls on journalists to instil public confidence and nurture excitement about science by being more diligent and responsible in their treatment of science. Relationships between scientists and journalists remained negative between the 1970s and 1990s. Scientists, concerned about inaccuracies and distortions in media coverage, became distrustful of journalists (Tankard & Ryan, 1974; Pulford, 1976; Moore & Singletary, 1985; Salomone, Greenberg, Sandman & Sachsman, 1990). In *Worlds apart*, a damning report on the science–media interface, Hartz and Chappell (1997) conclude that there was a deep estrangement between American scientists and journalists. Similarly, Dunwoody and Ryan (1985:26) note, "in a world full of eager information sources, scientists often stand out because of their reluctance to play that role".

Scientists' criticism on how journalists report on science includes oversimplification (Goodell, 1977; Burchell *et al*., 2009), inaccuracies (Bucchi & Saracino, 2012; Gonon, Konsman, Cohen & Boraud, 2012), a lack of expertise (Corley *et al*., 2011), sensationalism and hype (Goodell, 1977; Gregory & Miller, 1998; Weigold, 2001), speculation and overstating of risk (Gunter *et al*., 1999), bias in favour of certain individuals (Goodell, 1977), and false balance[43] (Nelkin, 1995; Weigold, 2001; Dixon & Clarke, 2012). Further complaints include failure to mention study limitations and the leaking of

[43] While balanced reporting (i.e. reporting both sides of an argument or differing opinions) is considered good journalistic practice, 'false balance' occurs when opposing views in science are presented as equal, without making it clear that scientific consensus favours favours a specific view, while the other view(s) has little or no support from the scientific community.

information prior to peer review (Kassirer & Angell, 1994; Schwartz, Woloshin & Baczek, 2002). On top of this, some scientists blame inaccurate or hostile media coverage for irrational public beliefs about science and dwindling public support for science (De Boer, McCarthy, Brennan, Kelly & Ritson, 2005; Burchell, 2007; Burningham, Barnett, Carr, Clift & Wehrmeyer, 2007; Krystallis, Frewer, Rowe, Houghton, Kehagia & Perrea, 2007; Young & Matthews, 2007; Blok *et al.*, 2008; TNS-BMRB, 2015). Furthermore, Petersen *et al*., (2009) show that scientists often have a one-dimensional conception of science mediation that overlooks the influence of their own claims, and therefore highlights the need for a better understanding on the part of scientists of their own roles in news production regarding science.

Journalists, it seems, harbour similarly negative perceptions and prejudices about scientists. They complain about scientists' excessive use of jargon and their inability to make their work understandable (Hartz & Chappell, 1997) as well as their general inaccessibility (Dijkstra *et al*., 2015).

The problematic relationships between scientists and journalists, and lamentations about the lack of quality science reporting in the mass media, are not limited to the Western world or the Northern Hemisphere. Frustrations about obscure language and elitism amongst scientists are shared by science journalists in Africa (Oriare, 2008; Kaye & Bakyawa, 2011; Clayton & Joubert, 2012). Claassen (2011) found that South African scientists and journalists hold different views about the role of science in society and how best to communicate science to the public. Outram (2010) find that, in Sub-Saharan Africa, a lack of trust and understanding between scientists and journalists continue to hamper public communication of science, with the result that African experts prefer to talk to journalists outside the African continent. Similarly, Lo and Peters (2015) list several studies that are critical of poor collaboration between Taiwanese scientists and journalists. Massarani and Peters (2016) report that Brazilian scientists' high expectations of how journalists should report on their work are not always met.

Given the complexities of science–media relationships, Nelkin (1995) believes that most scientists are ambivalent about working with the mass media. They regard it as necessary and desirable on the one hand but, on the other hand, they are concerned about the extended implications of public accountability that occur once information enters public discourse. Nelkin (1995) further points out various ways by which scientists try to control the images and information that appear in the media. For example, a scientist may refuse to do an interview unless the journalist agrees to allow them to review a copy of the article before going to print. Other authors agree that scientists have mixed feelings as far as media engagements are concerned. On the one hand, scientists recognise the power of the media but, on the other hand, they are concerned about journalists' objectivity and expertise (Gregory, 2001; Dijkstra *et al*., 2015; Massarani & Peters, 2016).

By contrast with these predominantly negative views, some prominent media scholars observe a more positive and stable relationship between scientists and journalists. Dunwoody (1982) reports that most scientists have contact with the media, they welcome media interactions and often take the first step to make contact. According to Dunwoody *et al*. (2009:209), scientists and journalists interact "more frequently than commonly assumed" and the pattern of interactions between science and the media "have remained remarkably stable over the course of at least three decades". Similarly, Peters and his collaborators have published a number of studies that point towards improving science–media relations, leading them to conclude that science–media interactions are "more frequent and smooth than was previously thought" (Peters *et al*., 2008a; 2008b). As a result of these improved relationships, scientists are becoming more willing and prepared to engage with journalists, and less concerned about issues such as simplification, sensationalism and even inaccuracies.

Wien (2014) agrees that relationships between scientists and journalists have become largely positive, constructive and mutually beneficial, while Peters (2014) adds that, in present-day research environments, most scientists consider visibility in the media important and think that it is their professional duty to respond to journalists' enquiries. These findings from the Northern Hemisphere are echoed by Southern Hemisphere reports of positive interactions between scientists and journalists in Brazil (Massarani & Peters, 2016).

In particular, visible scientists are tolerant of failings of the mass media, as highlighted by Goodell (1977:137):

> Visible scientists are remarkable tolerant of the press's failings – not blind to them, but not bothered. They give the press no prizes of accuracy, but they consider the overall quality of science reporting good. They have come to expect, and accept, inaccuracies in news stories. And they handle the problems with sophistication and perspective.

Yet, many scientists remain sceptical about the media. For example, in a study of American Association for the Advancement of Science (AAAS) members (Pew Research Center, 2015b), 79% of respondents were concerned about journalists' failure to distinguish between evidence-based findings and less credible findings, while 52% thought that simplification of scientific findings presented a major problem for science in general.

Despite lingering reservations about the media, surveys since the 1990s confirm that scientists recognise the power of the media in reaching public and policy audiences, even if they do not see it as a perfect tool to do so (DiBella *et al.*, 1991; Gascoigne & Metcalfe, 1997; Nielsen, Kjaer & Dahlgaard, 2007; Besley & Nisbet, 2013; Pew Research Center, 2015a). Scientists are well aware of the probable benefits of working effectively with journalists, but equally mindful of the potential pitfalls (Nelkin, 1995; Peters *et al.*, 2008a; Peters, 2013).

3.3.5. Attitudes towards social media[44]

> ***Digital technologies have shattered the public sphere; it is no longer a physical space to which people go, but multiple virtual spaces that come to them and whose importance lies in the nature of the communication and engagement that emerges.***
> *(Grand* et al.*, 2016:6)*

The current media landscape is highly fragmented and characterised by an ever-changing array of communication options. The dynamics of how people seek, access and process information has been transformed and continues to change. A dominant trend is the move away from traditional (print and broadcast) media towards consuming information from online sources (Anderson, Brossard & Scheufele, 2010; Brossard, 2013; Brossard & Scheufele, 2013).

Ironically, the invention of the World Wide Web (WWW) at the European Organization for Nuclear Research (CERN) in 1989 was primarily aimed at enabling collaboration within science. However, scientists have reacted with caution and many remain reluctant to employ online communication tools (Butler, 2005; Gregory, 2009). Consequently, scientists have been slower than mainstream society to adopt social media channels (Priem, Piwowar & Hemminger, 2012). Both scientists and journalists have been affected significantly by the digitisation of the communication landscape, and have experienced rapid change as traditional media structures crumbled in favour of online platforms and social networks (Trench, 2009).

Today, digital media have become pervasive and omnipresent in daily life. It differs from traditional media primarily because of its social, dialogic and participative nature which allows users to generate content, comment and engage in online conversations (Anderson, 2017). In this new communication landscape, individual and public communication are merging, and the barriers between communicators and audiences are disappearing (Peters *et al.*, 2014). Communication scholars generally agree that online and social media will increasingly become intertwined with traditional media, and that the prominence and influence of online and social media in science communication will continue to expand (Brossard, 2013; Brossard & Scheufele, 2013; Flaherty, 2016). Scientists increasingly use a blend of traditional and new media to communicate their research and monitor developments relevant to their field (Allgaier *et al.*, 2013a).

3.3.5.1. The risks and rewards of digital media

People are increasingly searching online for information about science (Brossard, 2013; Liang *et al.*, 2014) and therefore scientists, as well as professional science communicators, cannot afford to ignore digital communication. However, while online media tools offer a range of advantages, they also raise a multitude of concerns.

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[44] For the purpose of this discussion, the terms 'new media', 'digital media' and 'social media' are considered to be essentially similar and therefore used interchangeably. They all refer to online media platforms.

On the plus side, scholars have highlighted the interactive nature and unprecedented reach of digital media as key advantages in terms of making research publicly visible and accessible. In the online environment, scientists can interact in a virtual world, thereby "emancipating the public from a mono-directional communication dynamic" (Casini & Neresini, 2012:41). Online channels allow scientists to provide the public with an infinite amount and variety of science materials, including videos, animations, infographics, popular articles and more. This makes science more accessible, transparent and entertaining than ever before (Bucchi & Trench, 2014), while giving scientists access to global audiences (Montgomery, 2009), including audiences that were previously inaccessible (German National Academy of Sciences, 2017). Digital media tools grant scientists "more power than ever before to be pro-active about their public communication" (Dudo, 2015:770) since they no longer have to rely on journalists to become publicly visible (Peters *et al*., 2014). This is an attractive option for scientists who prefer direct interaction with the public (Casini & Neresini, 2012), as well as those who consider themselves better able to communicate the social and ethical implications of their research than journalists (TNS-BRMB, 2015).

On the negative side, many scientists perceive the digital environment as a high-risk terrain. In the online realm, there are no journalistic gatekeepers, which means that social media easily becomes a platform for spreading unfiltered, trivial, false or potentially damaging information and opinions (German National Academy of Sciences, 2017). Messages can be amplified, shared and reacted to at levels unimaginable before, but this also means that reputations can be shattered overnight (Dudo, 2015). The tone and personal nature of online exchanges can be particularly intimidating to the point where scientists may perceive that they are being attacked on a personal level (Mandavilli, 2011).

Weingart (2012) claims that social media may weaken science communication because of its potential to damage the credibility and image of science and scientists. Some scientists are concerned that unparalleled access to scientific information blurs the boundaries between experts and non-experts, thereby increasing the demand for scientists' accountability (Montgomery, 2009).

Further concerns about online communication relate to doubts about the quality of content and uncertainties about how people find and process information. For example, social science scholars have highlighted people's inability to distinguish credible information from dubious content or independent news from PR materials (Nisbet & Scheufele, 2009; Scheufele, 2013; Yeo *et al.*, 2015; Weingart & Guenther, 2016). A key concern in the developing world is uneven access to online information, which excludes large parts of society (Hornig Priest, 2009; Gastrow, 2010).

In a critical reflection on the escalating use of social media in science communication, Weingart and Guenther (2016) argue that scientists who promote themselves via Facebook, Twitter, YouTube and blogs are simply vying for maximum public attention, something that has become an independent objective for a substantial share of scientists. The authors question the integrity of this kind of science communication, as well as whether undifferentiated social media audiences are appropriate for science. They highlight the lack of quality control and critical assessment that characterises social media, and express concern that social media may lead to an erosion of trust in science.

Despite these reservations, many scholars agree that digital media and social networks will transform the relationships between science and society, and even science itself, fundamentally over time (Fausto, Machado, Bento, Iamarino, Nahas & Munger, 2012; Peters *et al.*, 2014). These digital platforms increasingly force scientists to rethink how they interact with their publics (Brossard & Scheufele, 2013).

3.3.5.2. How scientists are responding to new media

The progressive spread of digital media has enticed science communication scholars to explore its influence on the science–society interface. In the context of this study, scientists' motivations to use (or avoid) social media were of particular interest.

In general, scientists have been urged to adopt social media as a tool to engage public audiences and peers, as well as to gain scientific reputation and influence (Van Eperen & Marincola, 2011; Bik & Goldstein, 2013). Emerging evidence suggests that some scientists are responding enthusiastically and using these communication tools in ever more sophisticated ways (Montgomery, 2009; Priem & Costello, 2010; Priem *et al.*, 2012; Allgaier *et al*., 2013b; Hall, 2014; Bombaci *et al*., 2016). Brossard (2013) states that scientists are embracing new media at a faster pace than researchers are able to examine these processes. Dudo (2015) underlines the need for more research into scientists' social media use and online engagements.

However, many scientists do not use or like social media. The rate whereby scientists adopt new media is uneven (Scanlon, 2012), and the proportion of scientists who frequently use social media is still relatively low (Collins, Shiffman & Rock, 2016). Time pressures, unfamiliarity with new media tools and a lack of support to develop new skills deter scientists from using new media (Regenberg, 2010; Bik & Goldstein, 2013). Others simply view social media as an unsuitable platform to communicate their work, because they see it as silly or frivolous and a waste of time (Esposito, 2013; Collins *et al.*, 2016).

Twitter, a microblogging platform and social networking tool, has emerged as a particularly popular and powerful science communication tool. Scientists use it to share and discuss peer-reviewed research with fellow scientists, as well as to engage policymakers and public audiences (Darling *et al.*, 2013; Yeo, Cacciatore, Brossard, Scheufele & Xenos, 2014; Collins *et al.*, 2016). Twitter has been shown to contribute significantly to researchers' influence, not only in society, but also within academic circles. Liang *et al*. (2014) show that research articles tweeted by prominent science reporters or science celebrities (for example Andrew Rivkin or Neil deGrasse Tyson[45]) attract far more attention, also from other scientists, than articles published in peer-reviewed outlets only,

[45] On 6 October 2017, Andrew Rivkin had 3.2 million followers on Twitter (Twitter handle @asrivkin), while Neil DeGrasse Tyson had 9.4 million followers on Twitter (Twitter handle @neiltyson).

including prestigious outlets such as *Nature* and *Science*. Twitter also amplifies the academic effect (as measured by h-indices) of scientists' collaborations with traditional media (Yeo, Brossard, Scheufele, Nealey & Corley, 2013), and increases scholarly visibility by boosting article downloads and citations (Eysenbach, 2011; Priem *et al.*, 2012; Brossard, 2013; Liang *et al.*, 2014).

By contrast with Twitter, research blogs, for example, conform more closely to the norms of appropriate academic behaviour, adding to its popularity and acceptance as a scholarly activity (Mewburn & Thomson, 2013). Blogging has been found to be a useful way to promote dialogue within science, as a place for conversations around a "virtual water cooler" (Kouper, 2010:7). However, as is the case for other online tools, blogging remains a rare and peripheral activity for most scientists (Lo & Peters, 2016).

3.3.6. Perceived moral duty

> ***Nothing in science has any value to society if it is not communicated, and scientists are beginning to learn their social obligations.***
> *(Roe, 1953:17)*

The social responsibility of any profession results from a process of negotiation, based on the tension between the "profession's pursuit of autonomy and the public's demand for accountability" (Frankel, 1989:110). In other words, society grants power and privilege to professions but, in return, expects these professions to contribute to the well-being of society and to adhere to certain social values. Thus, society expects of scientists to contribute to quality of life and prosperity.

The idea that scientists owe a moral duty to the public stems from the argument that the bulk of research is done with public money. Therefore, the public has a right to know what the money is used for and what the returns on these investments are, implying that scientists can pay their debt to society through public engagement (Borchelt, 2001; Greenwood & Riordan, 2001; Dickson, 2010; Marcinkowski et al., 2014; Ren *et al*., 2014). As stated by Reddy (2009:1405):

> For scientists, one often-overlooked responsibility is explaining their work to people. This is not an unreasonable price for receiving public funds to do research. And it promises to combat ignorance, guide sound policymaking, and garner more support for science, while simultaneously inspiring and recruiting new young scientists.

The centrality of science to modern life is used as an argument that scientists have an obligation to nurture close links with society (Leshner, 2003). For example, the National Academies of Sciences, Engineering and Medicine (2017) state:

> The intimate, mutually supportive relationship between science and society places a responsibility on scientists and technologists, as citizens, to share the results of their work with the broader public so they can reap its benefits as expeditiously as possible.

Bakuwa (2014) agrees that public participation in science is an essential component of the democratisation of science, since issues rooted in science affect everyone in society. The author adds that denying people the opportunity to engage with science and scientists lead to a deterioration in the relationships between science and society.

The value afforded to public science communication as a cornerstone of democracy adds impetus to the notion that scientists are morally obliged to make their work accessible to the public (Braun *et al.*, 2015; Lewenstein, 2016), especially when they work in contested fields of research (European Commission, 2007; Stilgoe & Wilsdon, 2009; Torres-Albero *et al.*, 2011; Marcinkowski *et al.*, 2014).

The cultural value of science provides another argument in favour of the view that scientists should share their work with society. The argument is based on the belief that people have a right to access and enjoy science, since science enriches their lives (Greenwood & Riordian, 2001; Sánchez-Mora, 2016). In this regard, a Royal Society report (Bodmer, 1985:10) states:

> Without some understanding of science, an individual is cut off from much of the richness of contemporary human thought. Indeed, whatever the benefits of public understanding of science may be, the intrinsic contribution of science to our culture argues that imparting such understanding is a duty the scientist owes to the public.

Peters (2017) argues that, based on the ethos of science, there is not necessarily a moral duty on scientists to communicate with the public. Instead, their duty is to find the truth. The discourse within science is to find the truth, while the discourse outside science is to provide the truth. However, Peters adds that the ethos of science has two key implications for public communication of science, namely when scientists speak in public, they have a special responsibility to speak the truth; and there is a moral duty on scientists to speak to public audiences if doing so could help them to find the truth.

Looking at this issue in a multi-cultural society like South Africa, Manzini (2003) makes a morally based case for the duty of scientists to share their work, particularly with disadvantaged communities. The author argues that the role of science in society is related to social justice and equity. Based on the premise that access to science can make people’s lives more manageable, improve their self-esteem and open up new opportunities, Manzini appeals for improved communication between scientists and “forgotten communities who eke out their livings on the margins of society”, including “rural communities, the homeless, the unemployed, and people living in informal settlements”; and implores scientists to communicate in a way that does not alienate people, but rather helps to “bridge the divide between what is known as science and the mundane struggles of life of the public” (Manzini, 2003:193).

3.3.6.1. Calls on scientists to communicate

Through the ages, scientists have been called upon to answer to a perceived duty to communicate outside the science arena. Leaders in the scientific world urge scientists to translate their results into accessible formats, and to make these available to journalists, policymakers and the public (Binder, Cacciatore, Scheufele, Shaw & Corley, 2012). These demands are amplified by the prominence and influence of the people who have been issuing these calls, thereby adding impetus and legitimacy to public communication of science. A few pertinent examples follow below.

In 1969, Morrison (1969:154) urged scientists to realise that they could no longer present science as an activity independent of society.

> The scientific community must re-double its efforts to present science – in the classroom, in the public press, and through education-extension activities of various kinds – as a fully understandable process, justifiable to man and controllable by him. Scientists should also take more responsibility for foreseeing and explaining the long-term effects of new applications of scientific knowledge.

Glass (1993:38), a former president of AAAS, described the obligation of scientists to communicate science to the public as a duty in the name of democracy, because "democracy rests secure only upon a basis of enlightened citizens who have imbibed the spirit of science and who comprehend its nature as well as its fruits''.

In the environmental community, Lubchenco's (1998) call for a new social contract between science and society is widely credited as a turning point for scientists to accept responsibility for sharing their expertise with policymakers and the public (Groffman *et al*., 2010; Smith *et al.*, 2013; Kuehne *et al*., 2014; Hoffman, 2016). Such a new social contract implies that "science must leave the ivory tower and enter the agora" (Gibbons, 1999:84).

A former NSF director, Neal Lane, urged scientists to accept responsibility for informing citizens about the importance of science and technology, or risk losing public support (Lane, 1996:1037):

> I believe that the new leadership needed from those of us in the research community – particularly from individual scientists and engineers active in research – is to carry our understanding of science and its value into the lives of all Americans.

During his term as chief executive officer of AAAS, Alan Leshner (2003:977) advocated for scientists to become better and more active public communicators, and specifically to move away from top-down communication towards respectful dialogue.

> The centrality of science to modern life bestows an obligation on the scientific community to develop different and closer links with the general population. We need to engage the public in a more open and honest bi-directional dialogue about science and technology and their products, including not only their benefits but also their limits, perils, and pitfalls. We need to respect the public's perspective and concerns even when we do not fully share them, and we need to develop a partnership that can respond to them.

In 2016, Napolitano (2016), president of the University of California, lamented the absence of questions about science and innovation during the presidential elections in the United States, adding that public dialogue about science was perhaps the most vital and most fraught national conversation not taking place in that country. She believed that it was incumbent on the academic community to ensure that the work and voices of researchers were heard more prominently.

According to Foley (2016), a failure to encourage and support scientists in terms of sharing their research with society constitutes a moral failure on the part of science and academia.

> As scientists, we owe it to the world to do a better job communicating the wonders of science, and the incredible discoveries being made by our field, to everyone around us. And in this moment of history, when addressing scientific issues has never been more urgent and important, we have a

> special duty to share our knowledge, expertise, and passion with the wider world. It is part of our social compact as scientists.

Similar calls from prominent science leaders regularly reverberate in the science community in the United Kingdom. In 1985, The Royal Society published an influential report that legitimised public science communication (Miller, 2001). The official title was 'The public understanding of science', but the report is commonly referred to as the 'Bodmer Report' after the chair of the working group, Sir Walter Bodmer. This report states (Bodmer, 1985:24), "[o]ur most direct and urgent message is for the scientists – learn to communicate with the public, be willing to do so, indeed consider it your duty to do so."

A decade later, another UK government report, this time from a committee appointed by the UK Office of Science and Technology (Wolfendale Committee, 1995), reiterated the notion that scientists, especially recipients of research grants, must engage the public. The report suggested that science communication demands should be reflected in funding agreements. In 2000, the UK House of Lords (2000) recommended that dialogue with the public should shift from being an optional add-on, towards becoming an integral part of the process of research and science policy-making. Over the years, several more eminent figures in the United Kingdom added their voices to these calls. Sir David King, chief scientific advisor for the UK government from 2000 to 2007, advocated for a new code governing the moral conduct of scientists. He called on scientists to accept responsibility for communicating and reflecting on the issues their work raises for society, with the overall aim of renewing public trust in science (Doubleday, 2009). Sir Martin Rees, president of The Royal Society from 2005 to 2010, is credited as one of the advocates for greater engagement between scientists and the public (Jensen *et al.*, 2008). On the occasion of the 350th anniversary of The Royal Society, Rees said (cited in Bryson, 2010:469):

> There can be no better aim, for the next fifty years, than to sustain the curiosity and enthusiasm of our founders, while also achieving the same broad engagement with society and public affairs as they did.

Drayson (2009) underscored the view by the UK government that publicly funded scientists had a duty to engage as follows:

> The UK government believes that scientists have a duty – particularly when they are funded by taxpayers – to engage in the public area, to engage in communication of the challenges and the potential ethical concerns about their science.

3.3.6.2. How scientists respond to the public duty to communicate

Scientists' motivations to participate in public communication depend, at least in part, on whether they regard it as an optional activity, an institutional responsibility or a personal obligation (Searle, 2013). Studies consistently show that many scientists do perceive a responsibility for communicating their findings to the public and that this generally motivates them towards getting involved (Mathews *et al*., 2005; The Royal Society, 2006; Miller & Fahy, 2010; Corley *et al*., 2011; Felt & Fochler, 2012; Wien, 2013; Dijkstra *et al*., 2015). This holds irrespective of gender, age, discipline or employer (Searle, 2011). Eight out of ten Swedish researchers believe that dialogue with the public is an “obligation of every researcher” (Vetenskap & Allmänhet, 2003:9). Similarly, the vast majority of scientists in the United Kingdom and the United States agree that they have a duty to communicate and debate their findings (MORI, 2001; Pew Research Center, 2015). Some scientists feel strongly about their duty to “use their expertise to criticise political, economic, and other decisions affecting society and to make practical suggestions for action” (Massarani & Peters, 2016:7).

The fact that the public pays for research is a key reason why scientists feel obliged to communicate (Mathews *et al*., 2005; European Commission, 2007; Dudo, 2013). Scientists frequently say they want to give something back to the patients, charities and others who supported or participated in their research (Burchell *et al*., 2009). Some scientists claim that they are compelled by moral considerations to communicate with the public, and not by professional promotion or public recognition (Torres-Albero *et al*., 2011). They frequently describe public engagement as “the right thing to do” (Grand *et al*., 2016:9), and even as a “noble activity” (Molinatti & Simonneau, 2015:191). Scientists’ perceptions of a personal duty to communicate their work to the public may be so strong that they will persist with external communication activities, even when faced with obstacles and negative feedback from peers (Van der Auweraert, 2008).

Controversies heighten scientists’ perceptions of the need to communicate. Those working in contested fields of research may feel a strong sense of duty towards pro-active engagement (The Royal Society, 2006; TNS-BMRB, 2015). This was shown for scientists involved in a French shale gas controversy (Molinatti & Simonneau, 2015) as well as for German biotechnologists (Braun *et al*., 2015). On this topic, Wilsdon and Willis (2004:18) state:

> The science community has embraced dialogue and engagement, if not always with enthusiasm, then at least out of a recognition that BSE, GM and other controversies have made it a non-negotiable clause of their licence to operate.

Contrastingly, astronomers, understandably less concerned with the everyday implications of their work, view public communication as a hobby rather than a duty (Dang & Russo, 2015).

While many scientists accept a primary responsibility for communicating with the public and rarely question the legitimacy of public engagement activities in contemporary democracies (Braun *et al*., 2015; TNS-BMRB, 2015), there are also scientists who reject the notion that they have a duty to communicate with the public (Bond & Paterson, 2005; Grand *et al*., 2015). Notably, even when scientists agree that they have a duty to communicate, it does not mean that they will necessarily do so. Poliakoff and Webb (2007) show that a perception of duty does not significantly influence scientists’ intention to participate in public communication. However, Tsfati *et al*. (2012) found that scientists’ beliefs that media engagement is part of their duty is an important predictor of their efforts to work with the media.

3.3.6.3. Differing perspectives on the notion of duty

Not everybody is convinced that scientists are sincere when they claim that they communicate in response to a perceived sense of duty. Sceptics question whether the “sense of social responsibility runs very deep in the scientific community” (Goodell, 1977:96). Instead, it is suggested, scientists may be driven by the desire to defend science, raise money and attract public attention (Goodell, 1977; Borchelt, 2001; Weingart & Guenther, 2016).

For their part, universities and other science organisations reinforce the notion that scientists have a duty to communicate to the public, for example by responding to media enquiries. These institutions welcome the profiling of their staff in the media (Peters, 2013). However, this institutional reinforcement may be driven by the reputation-building motives of research organisations. In their study, Martín-Sempere *et al*. (2008) found that scientists correlate their sense of duty most closely with the objective of making their research centre well known and visible to the public. In other words, scientists see it as a duty to promote their institution, rather than as a duty to give something back to the taxpayer. Weingart and Guenther (2016) agree that the idea of democratic duty is mistakenly translated into competition for attention, and that universities use the perceived obligation of public accountability as an excuse for institutional promotion, aimed at legitimising research funding.

3.3.7. Perceived self-efficacy

> ***Collectively, we agree that scientists need to be good communicators, but communicating science to laypeople is not a trivial task.***
> *(Brownell, Price & Steinman, 2013:e6)*

There is a commonly held view that scientists are poor communicators (Hartz & Chappell, 1997; Olson, 2009; Radford, 2011). As such, their perceived inability to communicate effectively is frequently blamed for the alleged disconnect between science and society (Hoffman, 2016). Scientists themselves frequently agree that they feel ill equipped to participate in public debate about the social and ethical implications of their work (Worcester, 2002; Lundy, Ruth, Telg & Irani, 2006; TNS-BMRB, 2015).

However, Radford (2011:455) says that it is a myth that scientists “are hopeless at explaining their work to a general audience”, arguing that their “natural gifts” of enthusiasm, knowledge, observation and clarity, ideally equip them to communicate. He acknowledges, however, that scientists’ training in academic communication, and the typical style of journal articles, make it hard for them to explain their work to lay audiences (Radford, 2011).

Commenting on the differences between scientific and public communication, Baram-Tsabari and Lewenstein (2012:80) say that they are “intrigued by the idea that scientists may need to ‘unlearn’ the communication skills they have acquired as scientists” in order to become better at public communication. The authors (2012:80) acknowledge tensions between scientific and public discourses by saying, "[o]ne rewards jargon, the other penalizes it; one rewards precision, the other accepts approximation; one rewards quantification, the other rewards storytelling and anecdotes."

The role of self-efficacy as a predictor of scientists' public communication behaviour has been demonstrated empirically (Poliakoff & Webb, 2007; Besley *et al*., 2012; Dudo, 2013; Besley, 2014; Dudo *et al*., 2014). Across different countries and disciplines, studies consistently show a positive correlation between training and researchers' belief in their own communication abilities, as well as the frequency of their participation (e.g. Gascoigne & Metcalfe, 1997; Gunter *et al*., 1999; MORI, 2001; Ruth *et al*., 2005; Besley & Tanner, 2011; Crone *et al*., 2011; Dudo, 2013; Ecklund *et al*., 2012; Dijkstra *et al*., 2015; France *et al*., 2015; TNS-BMRB, 2015). In particular, scientists who believe they have the prerequisite skills, will interact frequently with journalists (Pitrelli *et al*., 2006; Dunwoody *et al*., 2009) and are likely to participate in other types of public communication (MORI, 2001; European Commission, 2007). Comparatively, scientists who are unsure about how to communicate are less inclined to participate (Holland, 1999; MORI, 2001; Andrews *et al*., 2005; BBSRC, 2014; Braun *et al*., 2015). In particular, a lack of skills deters scientists from using new media tools (Priem *et al*., 2012; Chikoore *et al*., 2016). Furthermore, scientists prioritise activities where they feel most confident (Dudo & Besley, 2016) and they tend to rate these activities as more important than others (The Royal Society, 2006).

Around the world, leaders in science have highlighted the need to equip scientists with engagement skills and research organisations have responded by creating such training opportunities (Leshner, 2007; Baram-Tsabari & Lewenstein, 2012). Some courses target leaders in science, while others focus on early-career scientists (Craig, Lerner & Poe, 2009; Brownell *et al.*, 2013; Devonshire & Hathway, 2014; Karikari, Yawson & Quansah, 2016). Support for science communication training also comes from policy circles. For example, the UK House of Lords (2000) strongly encourages communication training for scientists at research councils and universities. The US-based AAAS has established the Center for Public Engagement with Science and Technology focus on providing science communication training and support for scientists at all career levels (AAAS, 2016). The nature and efficacy of these training programmes have attracted the attention of numerous scholars (Silva & Bultitude, 2009; Miller & Fahy, 2010; Besley *et al.*, 2015; Rodari & Weitkamp, 2015). There is some concern that the persistent focus on knowledge transmission (i.e. top-down, one-way communication) will perpetuate the lack of skills in public dialogue, and therefore will fail to prepare scientists for meaningful public engagement (Edmondston, Dawson & Schibeci, 2010; Besley & Tanner, 2011; Palmer & Schibeci, 2012; Trench, 2012).

3.3.7.1. Skills that shape scientists' perception of self-efficacy

Some scientists have an inborn ability to communicate well and even "a talent for popularising" (Goodell, 1975:22), but most struggle to make their work accessible and meaningful to lay audiences and generally do not fare well when called upon to engage in public debate (Chalmers, 1999). However, with training and experience, scientists are able to refine their communication skills and gain confidence (Radford, 2011; Brownell *et al.*, 2013; Horst, 2013). Given the importance of perceived self-efficacy as a factor that influences scientists' willingness to communicate in public, it is important to clarify the skills that scientists need in order to be successful public communicators.

Scholars who have studied visible scientists and their communication abilities (Goodell, 1975; Baram-Tsabari & Lewenstein, 2012; Fahy & Lewenstein, 2014; Fahy, 2015; Besley, Dudo, Yuan & AbiGhannam, 2016) suggest a specific skills set required for effective public engagement. Similar skills are reflected in practical science communication guides (Dean, 2009; Baron, 2010a; Olson, 2009) and science communication training programmes (Miller & Fahy, 2010; Illingworth & Roop, 2015). These include the ability to:

- understand and connect with relevant audiences;
- explain the essence of a new piece of research clearly, vividly and accessibly, without the use of jargon, and without caveats, qualifiers and disclaimers;
- present new evidence that states a case strongly and unequivocally;
- craft compelling and memorable messages;
- use imagery, analogies and metaphors when explaining complex topics;
- tell a good story that grabs attention;
- make research relevant, meaningful and practical for specific audiences;
- engage in respectful and constructive dialogue; and
- put a research project in the context of a broader picture.

Science communication trainers accentuate that effective communication is not only about what is communicated (content), but also (more importantly) how it is communicated (style) (Dean, 2009; Olson, 2009; Weiler, Keller & Olex, 2012). However, scientists may fear that visible excitement about their work may call their objectivity into question, causing them to suppress their enthusiasm when they speak in public, in favour of a dry and technical style (Walters & Walters, 2002).

3.3.8. Personality

> ***As a rule, scientists are not well suited psychologically for the job of communicating with the public.***
> *(Goodell, 1977:90)*

Goodell (1977:90) describes scientists as "aloof, isolated from society, absorbed in their work, and uncomfortable in interpersonal and political situations". These characteristics are not ideally suited for public communication. In addition, Rödder (2012) found that scientists locate their own unease about public appearances in their personality structure, referring to themselves as being media shy. Quite possibly, the same personality traits that make scientists indispensable sources of new information may also be distancing them from lay people (Fischhoff & Scheufele, 2013). However, other authors suggest that, armed with knowledge about their own personality traits, scientists are able to improve their communication capabilities and cultivate a communication style with which they are comfortable (Weiler, Keller & Olex, 2012; Rosen, 2016). Introversion, Cain (2012) argues, is not a personality flaw, but rather an opportunity to engage in different ways, for example by using social media instead of mainstream media.

3.3.8.1. Personality traits of publicly visible scientists

Historically, some scientists stand out as gifted communicators with outgoing personalities. Dudo and Besley (2016) highlight Carl Sagan and Stephen Jay Gould as eloquent communicators for whom engaging with the public came effortlessly.

Locally, South African heart pioneer Christiaan Barnard became a global media sensation after performing the first successful human-to-human heart transplant in Cape Town on 3 December 1967. He is described as a charismatic and entertaining speaker with a sense of humour who mixed with the rich and famous and became known as something of a playboy (Cooper & Cooley, 2001; Brink & Hassoulas, 2009:31). According to Hoffenberg, Barnard indulged in the media attention in a rather impetuous, flamboyant and undignified way. He describes Barnard as "egocentric, hardworking, clever, ambitious, brash, and somewhat arrogant" (Hoffenberg, 2001:1479).

South African journalist Alex Eliseev describes palaeontologist Lee Berger as one of those rare scientists with flare and personality, a scientist with the so-called X-factor, who has the talent to make science exciting and entertaining (Eliseev, 2015).

Goodell (1975:1) contrasts the personality traits of the 'typical scientist' with those of high-profile, publicly visible scientists. This is how she describes the stereotypical scientist.

> A pale, thin, balding professor in a white laboratory coat steps to the microphone, blinks uncomfortable at the bright camera lights, unfolds a prepared statement from his pocket, and reads it verbatim in a quavering voice. He is then subjected to polite questions from reporters, which he answers in muddy, technical terms. He is not a people person, and certainly not a press person. He lives in isolated splendour, consumed by his work, and dies in obscurity, understood only by his colleagues.

In sharp contrast to this bland and demure individual, visible scientists are confident and outspoken, constantly exploring new pathways for influence and able to adjust to cutting-edge communication technologies (Goodell, 1975). Speaking from personal conscience and not group consensus, they are often outsiders, even outcasts, in the scientific community. They are strong and assertive individuals who dominate conversations and "thrive at the centre of attention" (1975:50). Adding that visible scientists are often scientific revolutionaries who question established theories, look for new approaches and advocate for change, Goodell describes them as "mavericks, tilting with the establishment" (1975:36), and even "gladiators" and "gadflies" in their professions and society at large (1975:39). Most importantly, the visible scientist has "a hot topic, is controversial, is articulate, has a colourful image, and has established a credible reputation" (1975:25). Goodell concludes that visible scientists are different and unusual, and not scared of controversy or notoriety. She highlights the personality types of some of the visible scientists she studied as follows: Margaret Mead was outspoken, Paul Ehrlich was charismatic, and Isaac Asimov was blatantly immodest and an egoist.

Goodell (1977:38) notes that the characteristics (or skills set) that make scientists visible are often the same that make for success in science: "ambition, energy, inquisitiveness, creativity, facility at explanations, organizational ability, aggressiveness, intelligence". She quotes Howard Simons (Goodell, 1977:38) as saying, "[i]t is the people with these characteristics who reach influential positions, not the silent people – the people who need lots of sleep."

Notably, not all iconic scientists seek out or enjoy public attention. For example, Einstein is described as a shy genius who was dismissive of his own fame and routinely refused invitations to speak in public, preferring to be left alone to do his work (Fee, 2014). In 1919, a month after his theory of relativity made media headlines, Einstein was overwhelmed by the publicity and, according to his biographer, Ronald Clark, Einstein wrote that it was "so bad that I [could] hardly breathe, let alone get down to sensible work" (quoted in Goodell, 1977:121).

3.3.8.2. Personality type and public science communication

Despite the obvious expectation that someone with an outgoing personality would be more likely to engage with the public, and that shyness may cause some scientists to be more reticent in this regard, it is rare to find empirical studies investigating the effect of scientists' personality types on their involvement in public communication. This is probably due to the inherent challenges of determining and measuring personality traits, since personality traits are latent, hypothetical constructs that can only be inferred from a wide variety of observable responses (Ajzen, 1988).

While we have limited empirical evidence of a link between scientists' personalities and their communication behaviours (Van der Auweraert & Van Woerkum, 2007), one relevant study was located in my literature review. Tsfati *et al. (*2011) investigated the degree to which researchers' personality traits predisposed them to approach or avoid media exposure. As expected, shyness and introversion make scientists less willing to agree to media interviews, while extroversion (being outgoing and eloquent) makes individuals stand out as attractive sources to journalists.

In recognition of differences in personality, there is broad agreement that some scientists may simply not be suited to public visibility. Consequently, the idea that public communication should be demanded of all scientists does not sit well with many academics. Instead, it is suggested, research organisations should identify those scientists who are motivated, interested and able to communicate, and focus on supporting them (Holland, 1999; Pearson, 2001; Dudo, 2013).

Furthermore, the desirability of public visibility in science remains contested. Some experts in the field of science communication claim that scientists who are confident, well-spoken and able to sell their ideas, have a competitive advantage over their more timid peers in terms of research impact and influence (Baron, 2010a,b; Harkness, 2015; Rosen, 2016). Others take a more critical view, arguing that scientists who achieve public visibility due to their flamboyant personalities and flair for public relations, do so primarily for self-promotion, financial gain and to compete for attention (Lievrouw, 1990; Weingart & Guenther, 2016). Similarly, Martín-Sempere *et al*. (2008:357) suggest that visibility in itself may motivate some ego-driven scientists to aim for public prominence, because for them it is "the cherry on top" of their careers.

3.3.9. Perceived benefits and rewards

> ***There is immense enjoyment to be had from communicating science.***
> ***You have a fascinating piece of experience to convey and there is great personal pleasure to be had from conveying it well.***
> *(Shortland & Gregory, 1992)*

When individuals perceive that their work is valued, they experience feelings of satisfaction and fulfilment that can be characterised as intrinsic rewards. Scientists who participate in public communication are motivated by such rewards (Dunwoody *et al*., 2009; Dudo, 2013). Communicating science is frequently framed as a rewarding and pleasurable experience (Gastel, 1983; MORI, 2001; Andrews *et al*., 2005; Poliakoff & Webb, 2007). For many scientists, communicating their knowledge to the public matters at a personal level (Searle, 2011) and is linked to their sense of self-identity (Watermeyer, 2015). They are motivated by the belief that public communication is a worthwhile and socially important endeavour (Miller & Fahy, 2010). Driven by personal rather than professional motivations, some scientists step out to engage with public audiences despite seeing little or even no benefit for themselves (Poliakoff & Webb, 2007).

A number of surveys confirm that, for some scientists, the pleasure, satisfaction and fulfilment that they derive from engaging with the public matter more than extrinsic rewards such as money, status or promotion (e.g. Dunwoody *et al*., 2009; Kreimer *et al*., 2011). As such, enjoyment is an important factor to consider when exploring scientists' motivations for public communication (Dudo, 2013). Research confirms that many scientists enjoy communicating their work in public and delight in seeing the effect of their communication efforts on their audiences (Pearson *et al*., 1997; The Royal Society, 2006; Wilkinson, Bultitude & Dawson, 2011). Some also enjoy media interactions and are pleased about the publicity their research gets (Metcalfe & Gascoigne, 2009). Personal enjoyment is one of the most frequently mentioned reasons that scientists give for getting involved in public communication (Holliman & Jensen, 2009; Burchell, 2015; TNS-BMRB, 2015). Scientists who enjoy communication focus on goals such as informing and building trust rather than, for example, defending science and combating misinformation (Dudo & Besley, 2016).

Another persuasive motivation for public science communication is that science is a cultural pursuit, much like poetry and music, and therefore sharing it enriches the lives of both presenters and audiences (Thomas & Durant, 1987; Hofstein & Rosenfield, 1996; Greenwood & Riordan, 2001; Bell *et al.*, 2009; Felt & Fochler, 2012). In line with the idea that science is something that can be enjoyed, scientists are urged to let the public know that they find satisfaction and enjoyment in their work. For example, the 1998 strategic plan of the US National Science Board asks of scientists to "communicate the joy and fascination of science as well as its utility" to society at large (National Science Board, 1998:15).

In addition to enjoyment, scientists reap several other intrinsic rewards from public engagement, such as personal development, renewed enthusiasm for research, personal satisfaction and feelings of self-esteem from making a contribution to the public good (Pearson *et al*., 1997; DiBella, 1999; MORI, 2001; Searle, 2011; Dudo *et al.,* 2014). Scientists find it personally satisfying to be sources of news stories for the media (Dunwoody, 1986; DiBella *et al*., 1991), while they also value public engagement activities as a way of "getting away from the research routine" and "a chance to meet other colleagues in another environment" (Martín-Sempere *et al*., 2008:358).

Scientists report that participating in public engagement increases their pedagogical and communication abilities (Storksdieck, Stylinski & Canzoneri, 2017). In particular, research students benefit from hands-on involvement in outreach, since it provides them with a platform to talk about the broader context of their work and to fine-tune their communication skills (Illingworth & Roop, 2015). Notably, engaging with the public may also help scientists to re-focus their work objectives and identify new research priorities. Burchell *et al*. (2009:52) report:

> Many of the interviewees' perceptions of the value of public engagement were based on first-hand experience of it, often accompanied by a 'conversion narrative' of sorts, in which interviewees described unexpected enthusiasm for this type of activity in spite of its potential limitations, time-consuming nature and unconventional demands.

Similar results emerged from other studies. Scientists get valuable feedback from publicising their work (Gascoigne & Metcalfe, 1997), explaining their work to others helps scientists to see its wider context and relevance (Pearson *et al*., 1997), communicating to the public provides new perspectives on own research and generate new ideas (Vetenskap & Allmänhet, 2003; Gustafsson, 2014; Flaherty, 2016). A UK survey revealed that some scientists believe that effective public communication requires a certain depth of insight that helps them to make new research inroads (The Royal Society, 2006). Dawkins (1999:xi) suggests that, when scientists push themselves to make their work more accessible to a general audience, it could lead to "a new way of seeing" which "can in its own right make an original contribution to science".

Foley (2016) summarises the intrinsic rewards of communicating science as follows:

> And, finally, to those skeptics out there – who aren't sure if science communication is worth the time and investment – I will share a secret with you: You're going to love it! Communicating your science with the broader world is one of the most fulfilling things you will ever do, and I guarantee you will find it fun, rewarding, and ultimately very educational. I have learned far more from my audiences, and the great questions they've asked me, than they have learned from me. Being a good science communicator has made me a much better scientist, and I am sure the same will be true for you too.

In contrast to the personal and abstract nature of intrinsic rewards, extrinsic rewards are about tangible benefits, such as funding, collaborators, students and citations (Dunwoody *et al*., 2009). The expectation that public communication could yield tangible rewards makes scientists positive and eager to participate (Tsfati *et al.,* 2011; *Dudo et al*., 2014), and may play a decisive role when scientists contemplate their involvement in public communication (Rödder, 2012). As such, extrinsic rewards are included in the list of factors expected to influence scientists' public communication behaviour.

Several studies have illuminated the benefits that scientists may reap from public communication. Getting involved in public outreach helps scientists to fulfil the expectations of their institutions (Pace *et al*., 2010). Visibility attracts students, since students perceive publicly engaged scholars to be knowledgeable, influential and credible (O'Brien & Pizmony-Levy, 2016). Public communication lifts scientists' recognition, not only the recognition they receive from the public, but also recognition amongst their colleagues, peers and policymakers, thereby establishing visible scientists as influencers and thought leaders (Dunwoody, 1986; Nelkin, 1995; Kyvik, 2005; Fahy & Nisbet, 2011; Peters, 2012; Kohring *et al.*, 2013; Smith *et al.*, 2013; Namihira-Geurrero, 2016). In particular, mass media exposure promotes career advancement and enhances visibility within and outside academia (Gascoigne & Metcalfe, 1997; Jacobson *et al*., 2004; The Royal Society, 2006; Kreimer *et al*., 2011; Dudo, 2013; Allgaier *et al*., 2013a; Besley *et al*., 2013; Dudo *et al*., 2014; Nisbet & Markowitz, 2015; Pew Research Center, 2015; TNS-BMRB, 2015; Massarani & Peters, 2016). Furthermore, mass media exposure amplifies academic impact by leading to more citations and/or article downloads (Phillips *et al*., 1991; Bauer *et al*., 2007; Eysenbach, 2011; Priem *et al*., 2012; Brossard, 2013). Kiernan (2003:8) provides evidence that coverage in mainstream newspapers increases the citation rates of the associated studies, adding, "specifically, each additional one hundred words of *[New York] Times* coverage was associated with seven additional citations of that journal article".

Some types of social media have a similar positive effect on citation rates. A study by Liang *et al*. (2014) confirmed that media interactions and Twitter mentions could contribute to scholarly impact. Public visibility has the potential to deliver financial rewards by attracting the attention of funders and increasing the success rate in funding applications. It may also help scientists to meet the requirements of funders, who increasingly expect of researchers to make their work publicly visible and accessible (Gascoigne & Metcalfe, 1997; Nelkin, 1995; Pearson *et al*., 1997; House of Lords, 2000; MORI, 2001; Pearson, 2001; Geller *et al*., 2005; Jensen, 2005; Kyvik, 2005; The Royal Society, 2006; Bauer *et al*., 2007; Wigren-Kristoferson *et al*., 2011; Palmer & Schibeci, 2014; Dijkstra *et al*., 2015; France *et al*., 2015; Koh *et al*., 2016).

Despite the anticipation of these tangible benefits associated with communication outside the academic arena, Rödder (2012) emphasises that aiming for public visibility remains an optional undertaking for scientists, adding that, in essence, the activity does not contribute towards academic reputation. That is because these rewards originate from outside the reward system within science, which emphasises the value of scholarly communication. The scientific reward system is more relevant and pertinent in most scientific careers compared to external rewards (Johnson *et al*., 2014).

3.3.10. Perceived risks and fears

> ***Indeed it sometimes seems to me that scientists are rewarded for publishing science – and punished for publicising it.***
> *(Cribb, 2011)*

Some scientists have serious concerns about becoming publicly visible. This fear could be a decisive factor, even if only for a minority of scientists (Claessens, 2008). Scientists' fears about public communication may stem from negative experiences in the past or anxiety about the anticipated consequences of future participation (TNS-BMRB, 2015). These fears are not unfounded, as some studies demonstrate the high-risk nature of public communication, as well as its occasional unintended and/or counterproductive effects (Porter *et al*., 2012; Johnson *et al*., 2014; Burchell, 2015). However, Shortland and Gregory (1992) point out that communicating science is never likely to be as risky as predicted by pessimists.

Scientists' concerns about public communication may be limited to particular platforms. Some scientists may be willing to speak to public audiences, but avoid media interviews (Rogers, 2015). In particular, online environments introduce new risks and apprehensions. For example, Liang *et al*. (2014) show that scientists worry about the potential spread of misinformation, polarisation of views and loss of credibility that may result from online dialogues. A Swedish study (Bärstad, 2014:47) further found that blogging scientists fear being seen as "light-weighted unserious clowns" or "self-involved, insecure, oversexed teens and twenty-somethings".

3.3.10.1. Fears about career impact

Due to the normative structure of science, public communication is often not recognised as a legitimate scholarly pursuit. Consequently, numerous studies over the last 50 years have found that scientists worry about the negative influence of a high public profile on their careers. These fears surface in some classic works in sociology, such as Warren O Hagstrom's book *The scientific community* (Hagstrom, 1965). It is similarly reflected in more recent studies (e.g. Miller, 1998; Jacobson *et al*., 2004; Martín-Sempere *et al*., 2008; Ecklund *et al*., 2012; Watermeyer, 2015a).

In terms of their careers, scientists fear disapproval from their colleagues, since some scholars look down on those who popularise science (Mathews *et al*., 2005; Ecklund *et al*., 2012; Porter *et al*., 2012). There is a perception that public communication could detract from academic credibility and reputation (Searle, 2011). More specifically, scientists fear that communicating in public could result in embarrassment, criticism or accusations of oversimplifying science (Goodell, 1975; Dunwoody, 1986; Hartz & Chappell, 1997; MORI, 2001; Weigold, 2001; Treise & Weigold, 2002; The Royal Society, 2006; Poliakoff & Webb, 2007; Winston, 2009; Besley & Nisbet, 2013; Cribb, 2011). Scientists are also scared of being accused of bias, especially when they endorse specific policies or advocate for a specific point of view (Vucetich & Nelson, 2010; Johnson *et al.*, 2014; Kotcher, Myers, Vraga, Stenhouse & Maibach, 2017). A related concern amongst scientists, demonstrated by Porter *et al*. (2012), is that public appearances will be seen by their peers as self-promotion, leaving the scientists open to allegations of unprofessional conduct.

3.3.10.2. Apprehensions about interacting with the media

Some scientists view media engagements as risky or even downright dangerous (TNS-BMRB, 2015). They may distrust journalists and agonise over their perceived unpredictability. They could be anxious about the risk that the media will distort, sensationalise or over-simplify their work (Gascoigne & Metcalfe, 1997; Van der Auweraert, 2008; Pew Research Center, 2015). In particular, scientists worry about being misunderstood, incorrectly quoted or misrepresented in the mass media (Shortland & Gregory, 1992; MORI, 2001; Gething, 2003; Poliakoff & Webb, 2007; Allgaier *et al*., 2013b; Pew Research Center, 2015; Rogers, 2015). As pointed out by Dunwoody *et al. (*2009), weighing up the benefits and risks of doing a particular interview may be of passing concern to a journalist, but could have long-term consequences for the scientist. Consequently, some scientists genuinely fear the perceived ability of journalists to damage their academic reputations (Colson, 2011). They also worry that, in the long term, some forms of media coverage may damage public perceptions of science (Nisbet *et al.*, 2002). Since premature public exposure may diminish scientists' chances of getting new research published, scientists are concerned about the leaking of unpublished research results and are therefore apprehensive about the timing of media interactions (Fink, 2016; Massarani & Peters, 2016).

3.3.10.3. Concerns over secrets and sensitive topics

Confidentiality and non-disclosure agreements in the case of contract, commercial or military research, as well as the desire to profit from patentable inventions, may further constrain scientists' participation in public communication (Jacobson *et al.*, 2004; European Commission, 2007; Small & Mallon, 2007; Davies, 2013b). Secrecy in science is fuelled by the protection of intellectual property, based on corporate and political interests (Ziman, 2000) and scientists may risk losing their research funding and or even their jobs if they reveal details of their research against the instructions of their sponsors or employers (Edmeades, 2009).

Given the increasing politicisation of science, researchers' views of the socio-political context of their own work influence their perceptions of the relative risks and benefits of going public (Scheufele, 2014). They may fear the potential repercussions when they communicate about sensitive topics or contested issues (Poliakoff & Webb, 2007; Ndlovu *et al.*, 2016). Scientists may prefer to sidestep public scrutiny and avoid debate with lobby groups who oppose their work (Gascoigne & Metcalfe, 1997; MORI, 2001; Weigold, 2001; The Royal Society, 2006).

Scientists who work in sensitive fields, for example animal testing, genetically modified organisms (GMOs) and stem cell research, face the added fears of potential threats or violent attacks on themselves and their families (Searle, 2011). In some countries, researchers may even face criminal prosecution should they dare to communicate politically sensitive findings in public (Ndlovu *et al*., 2016).

3.4. Literature review: contextual factors

3.4.1. National context

> ***Scientists, whose profession has been shaped by international trends, may behave differently towards science communication according to the culture in which they are embedded.***
> *(Massarani, 2015:4)*

Science is a global endeavour, and cultures, communication patterns, media landscapes, economies and political systems differ vastly around the world. These socio-political differences affect research environments and scientific conduct, and therefore also the interactions between scientists and public audiences (Lo, 2016).

Despite the global nature of public science communication, it has "distinctive regional characterisations" (Bucchi & Trench, 2014:11). As such, there are significant cultural variances in science communication, depending on the characteristics of audiences and value systems in different societal settings (Medin & Bang, 2014). In this regard, Sturgis and Allum (2004) underline the need to contextual information about science according to the specific culture, circumstances and needs of a given community. Further, science–media relationships vary from country to country (Peters, 2013) and scientists perceive different responsibilities toward public engagement depending on national contexts and cultural traditions (Crettaz Von Roten & Goastellec, 2015).

Culturally diverse societies and developing world settings present challenges in terms of science communication, for instance:

- Poor and illiterate communities have specific science communication needs, for example information about water, food, hygiene and diseases prevention (Lewenstein *et al*., 2002).
- In India, "obscurantism and superstitions are believed in as a routine" (Rautela & Chowdhury, 2016:487), while myths and superstitions also cause multiple social problems in South Africa and complicate communication of science with affected communities (Manzini, 2003).
- Language is a major barrier, and science communication is more effective when indigenous languages are used, as has been demonstrated in a rural South African setting by Fish, Allie, Pelaez and Anderson (2017).
- It is particularly challenging to effectively engage widely dispersed rural populations, spread over a vast country such as Brazil, as discussed by Massarani and De Castro Moreira (2015).
- Science journalism faces particular challenges in developing countries, including access to science news in South Africa (Clayton & Joubert, 2012), and a lack of institutional support and training in Ghana (Appiah *et al.*, 2015).
- Scarcity of funding and limited infrastructure further obstruct public health communication in a country like Uganda (Bakyawa *et al.*, 2013).
- The censoring of politically sensitive findings limit public communication of research findings in Zimbabwe (Ndlovu *et al.*, 2016).

3.4.1.1. Variations in regulatory and funding frameworks

Country-specific constitutional, legal and policy frameworks may encourage or inhibit science communication. For example, already in the 1960s, the Swedish government started demanding that scientists (and public universities) popularise their work, and listed science popularisation as a criterion when scientists were considered for promotion (Engwall, 2008).

In India, the concept of scientific temper[46] is promoted and protected by the 1976 Fundamental Duties Act (Rautela & Chowdhury, 2016). It obliges citizens to promote scientific temper: logical, rational and analytical thinking and a systematic, orderly way of acting. Indian science policy supports the dissemination of scientific knowledge as a way to develop scientific temper.

According to Qi *et al*. (2013), China was the first country to introduce a law promoting science and technology communication at a national level. The 2002 Law of the People's Republic of China on Popularization of Science and Technology provides legal protection and ensures policy support. It is considered a benchmark in Chinese science communication history. This legal framework is endorsed by the Chinese Natural Science Foundation and has resulted in policies that support and/or demand scientists' active involvement in public engagement. Similarly, the '2003 Act on Universities' in Denmark, establishes a regulatory framework for universities, which obliges these institutions to engage with the public (Nielsen *et al.*, 2007).

Some governments promote ethical codes of conduct for scientists that include a responsibility to engage with the public. The UK Universal Ethical Code for Scientists (Government Office for Science, 2007) emphasises scientists' responsibility for communication, including listening to public aspirations and concerns, and seeking to discuss the issues that science raises for society. Davies (2013) describes the rich network of policies and structures that support public science engagement in the UK as signalling widespread acceptance of its importance. Science policy recommendations in Germany suggest that scientists' participation in public engagement activities "should be eligible for reputation" (*Stifterverband für die Deutsche Wissenschaft*, quoted in Rödder, 2012:158).

3.4.1.2. Nationality and public science communication

Most surveys on the public communication behaviour of scientists so far have focused on researcher populations within countries, with very few studies paying attention to scientists in Africa. A small number of researchers have taken on the challenge of doing cross-country comparisons in their explorations of how and why scientists communicate with public audiences.

[46] According to Rautela and Chowdhury (2016:498) the concept of 'scientific temper' is well known in India. The authors explain that scientific temper has nothing to do with science, but is rather an attitude or mental construct, reflecting "one's logical, rational and analytical thinking, systematic and orderly way of his performance in all spheres of life, his reasonable behaviour and conduct in the society and of course a rational decision making power".

Despite marked differences in research practices between central and peripheral countries, Kreimer *et al*. (2011) report that patterns of science popularisation in Argentina do not differ substantially from those in France and the United Kingdom. Similarly, a 2007 study across EU member states found no significant differences in how scientists of different nationalities view the media (European Commission, 2007). Peters *et al*. (2008a) show that patterns of science–media interactions are surprisingly similar across the United States, Japan, Germany, the United Kingdom and France.

In contrast with the findings above, Bucchi and Saracino (2012) found that Italian researchers are less involved in doing media work, and less satisfied with their recent media appearances, compared to scientists in the United States, Japan, Germany, the United Kingdom and France. Several more surveys revealed distinct variations in the level of European scientists' participation in public engagement and media interactions (Escutia, 2012; Peters, 2013; Crettaz Von Roten & Goastellec, 2015). Bentley and Kyvik (2011) illuminate large country differences in patterns and frequencies of popular science publishing. The authors suggest a range of factors that could explain these variations, such as dissimilar normative influences, publishing traditions and incentive structures for scientists, as well as variances in the perceived pressures to legitimise research funding.

A few studies provide interesting East–West comparisons. Lo and Peters (2015; 2016) show that exchanges between Taiwanese scientists and journalists are more strained and less frequent compared to similar interactions in Germany and the United States, but find that Taiwanese scientists are comparatively more actively involved in online communication. Lo (2016) suggests that German scientists' slower uptake of online media could be explained by the fact that traditional media remain strong and dominant in Germany. A comparative study of scientists in China and the United Kingdom found that Chinese scientists are considerably less involved in public communication than their American counterparts (Ren, Liu, Wang & Yin, 2014). The authors conclude that this is due to low levels of institutional backing, funding and support, as well as the low value attached to public communication of science. This contradicts the opinion that a national law in China ensures a supportive public communication environment (Qi *et al*., 2013).

3.4.2. The institutional environment

> ***If a scientist does not have a wide personal reputation, he can get attention from the media by being associated with a widely known institution.***
> ***The chances are, reporters figure, if he has been hired by Bell Laboratories, or Harvard University, he is reputable and safe.***
> *(Goodell, 1975:53)*

Organisational culture and infrastructure are constituted by policies, norms, reward structures, expectations and corporate services. Its effect on the public visibility of research staff has been illustrated in several studies (e.g. Bauer & Jensen, 2011; Dudo, 2013; Entradas & Bauer, 2016). In fact, Edge, Martin, Rudgard and Thomas (2011) show that, in the complex set of factors that drive and shape the communication behaviour of scientists, institutional factors are very important and have much influence over the communication behaviour of individual scientists.

As expected, scientists communicate more frequently in public if this is a part of their job that is recognised and supported by their institutions (Searle, 2011; Besley, Oh & Nisbet, 2013). Visible approval and support from top management provide researchers with the necessary backing to get involved, and the reassurance that these activities are acknowledged and appreciated. “If these aspects are lacking, the positive attitude of the researcher towards science communication may evaporate” (Van der Auweraert, 2008:260).

Depending on their institutional character and values, universities attach more or less value to the public visibility of their staff. In the United States, for example, land-grant universities have a long tradition of engaging with the public. There are many notable examples, such as Michigan State University where outreach is recognised as a scholarly activity alongside teaching and research (Lunsford *et al.*, 2006). At the University of Wisconsin-Madison, ‘The Wisconsin Idea’ guides global outreach efforts, based on the principle that education, and therefore faculty members, should influence people’s lives beyond the academic environment (University of Wisconsin-Madison, 2016). In South Africa, for example, the University of Cape Town has adopted ‘social responsiveness’ as a strategic goal, with an emphasis on sharing new knowledge with society for the public good, and driven by the belief that societal engagement contributes to excellence in teaching and research (University of Cape Town, 2017).

Globally, universities are increasingly under pressure from funders and policymakers to strengthen their public profiles, and to make their research visible and accessible to external audiences (Weingart, 2012). Consequently, universities are increasingly looking for new ways to connect with the outside world (Powell & Colin, 2008; Felt & Fochler, 2012), and the value of public science communication is progressively recognised (Featherstone, Wilkinson & Bultitude, 2009; Wilkinson, *et al*., 2011; Casini & Neresini, 2012; Davies, 2013a; Grand *et al*., 2015). Universities therefore take a keen interest in the visibility of their star researchers, since the public profiling of research outcomes is a pathway towards legitimacy (Marcinkowski *et al*., 2014).

Institutional recognition of the strategic importance of public science communication goes hand in hand with investment in communication incentives and support structures. These signals from top leadership legitimise public science communication in competitive research environments (Dudo, 2013). Predictably, researchers are more receptive to participating in public communication when commitment is visibly demonstrated by top management and reflected in institutional mission statements, policies, rewards structures and incentive schemes (MORI, 2001).

3.4.2.1. The role of institutional research managers

Alongside institutional leaders, research managers are well placed to facilitate interaction between scientists and external audiences. Botha and Hunter-Hüsselman (2016) explain that research directors are keenly aware of new developments in their institutional research portfolios and noteworthy policy outcomes of research. These directors are the first to know about research achievements, awards and prizes, and they are up to date with the research statistics of their universities. The authors contend that, in South Africa, research directors at research-intensive universities emphasise the importance of the public visibility of research, along with demonstrating the social relevance and significance of research conducted at their institutions. While research directors and their staff often play a direct role in communicating with external audiences, for example via popular research magazines and online knowledge directories, they also work closely with their colleagues in institutional communication and marketing offices.

3.4.2.2. The role of institutional communicators

In the face of intensifying competition for research resources, universities are no longer leaving the task of communicating science to a small group of visible researchers. Instead, they expect a broad base of academics to respond to institutional expectations in terms of public visibility of science (Marcinkowski *et al.*, 2014). This leads to escalating demands that researchers should help to attract positive media coverage to promote the institution (Kyvik, 2005; Engwall, 2008; Peters *et al.*, 2008b; Rowe & Brass, 2011).

Successful public communication of science demands specialised knowledge of the mass and social media landscapes, as well as the ability to negotiate different interests, expectations and norms (Lo & Peters, 2015). Therefore, universities (and similar research organisations) appoint dedicated communication professionals who work as intermediaries between researchers and the mass media (Dudo, 2015). These PR professionals know how to identify research with news potential, and how to present it to the mass media with PR tools such as news conferences, press releases, photo opportunities, video clips and interviews (Shipman, 2014; Dudo, 2015; Shipman, 2015). They are able to apply their knowledge of news criteria and media logic to achieve media coverage for institutional research (Marcinkowski *et al.*, 2014), and they are able to adjust to journalistic expectations, despite the fact that these may conflict with scientific norms (Lo & Peters, 2015). They use sophisticated multimedia tools and strategies to increase the media appeal of the science news they generate, as well as to impress collaborators, funders and future students. It is the job of these PR officers to make their institutions look good, and they do so with a full understanding of the expectations and rules of the media (Peters *et al.*, 2008). As such, public relations has become a significant and inseparable part of the practice of public communication of science in research institutions (Autzen, 2014; Borchelt & Nielsen, 2014). Currently, university PR offices have a substantial effect on scientists' media efforts (Peters, 2008) and "institutionalised push communication" has become the dominant form of communication at academic institutions (Marcinkowski & Kohring, 2014:1).

3.4.2.3. The rise of science PR

While the status of PR in scientific organisations used to be marginal and scientists "overwhelmingly preferred direct contact with journalists" (Dunwoody & Ryan, 1983), the number of PR professionals within research organisations has grown significantly since the 1980s (Davis, 2000; Göpfert, 2007; Peters *et al.*, 2008; Trench, 2009; Borchelt & Nielsen, 2014; Weingart & Guenther, 2016). Moving away from the traditional role of providing information to the public, the function of PR has shifted to the pursuit of strategic reputation-building objectives (Peters *et al*., 2008b).

Several reasons have been suggested for this growth of science PR. Peters *et al.* (2008b:205) suggest that the "functional necessity of public science communication may be a global phenomenon in democratic knowledge societies". Weingart and Guenther (2016) agree that the drive to democratise science has become embedded in science policy and politically correct discourse and has spurred on the demand for scientists to communicate as widely as possible. The fact that this appeal to democracy synchronises well with institutional PR needs, further bolstered the popularity of science communication (Weingart & Guenther, 2016). Therefore, the increased focus on public communication of science can, at least partly, be attributed to changes in science governance and the increasing politicisation of science. Marcinkowski *et al*. (2014) point out that the mounting perception of a "new commandment" to communicate with the public, as highlighted by Gregory and Miller (2000:1), coincides perfectly with the way university managements have been reformed recently. In order to compete for scarce resources, universities must demonstrate that they are credible, relevant and socially responsive. Under these conditions, public communication of science becomes a tool to bolster institutional credibility and legitimise public funding (Dudo *et al.*, 2014; Marcinkowski & Kohring, 2014).

3.4.2.4. Science PR and scientists' public communication behaviour

Marcinkowski *et al. (*2014) demonstrate the effect of such a strategic orientation towards public science communication at institutional level. The authors show that scientists' interest and willingness to speak to the media are influenced by the PR practices and policies where they work, and whether or not they internalise the need for media visibility at the organisation. Scientists increasingly comply with media demands as they receive more requests to do so. Additionally, the circulation of press clippings, where scientists see the media efforts of their peers, makes some scientists willing to respond to media requests. This may even prompt them to take their own initiative in generating media interest in their work. This can be linked to competition between researchers for recognition within their institutions, which may encourage them to pursue public and media visibility to gain the desired level of prominence.

3.4.2.5. Institutional pressures on public science communication

Despite the expectation that institutional mediators would play a major role in the process of popularising science, studies in the 1980s (Dunwoody & Scott, 1982; Dunwoody & Ryan, 1983) found that they did not have much influence on scientists' attitudes toward the press. By contrast, a 1991 study (DiBella *et al*., 1991) found a clear link between the type of institution where scientists worked and their willingness to be interviewed by journalists. Since then, several studies have confirmed that scientists are encouraged and motivated to participate in public science communication when the organisations where they work recognise, support and encourage their efforts (The Royal Society, 2006; Poliakoff & Webb, 2007; Dudo, 2013; France *et al*., 2015; Entradas & Bauer, 2016).

Marcinkowski *et al*. (2014) demonstrate the powerful influence of well-equipped and active PR offices on stimulating scientists' media efforts, and conclude that organisational factors are more important in determining frequency of interaction between scientists and journalists than the field of research.

However, there are also other factors at work within institutions that affect scientists' communication efforts. Bucchi (2015:241) discusses the influence of the so-called "Matthew effect" or "halo effect". This is based on the notion that scientists who are employed by prestigious universities or belong to prominent research groups are rewarded with increased attention and higher public visibility, making it easy for them to attract resources.

3.4.2.6. Concerns over PR influences

While institutional communicators play an important bridging role between research organisations and external audiences, the job of these communicators is first and foremost to present their institutions in a favourable light. As such, they are primarily interested to maximise positive, reputation-building publicity for their institutions. They use brand-building and promotional communication, and they have strategies to cope with negative media coverage (Engwall, 2008) and are not really interested in facilitating public dialogue about science (Claessens, 2014). In the interest of protecting the image of the institution, they may restrict scientists when it comes to speaking openly about controversial research (Searle, 2011). The emphasis on institutional promotion comes at the expense of other types of science communication and may place limits on scientists who want to engage in societal dialogue (Peters *et al*., 2008a; Marcinkowski & Kohring, 2014).

Marcinkowski and Kohring (2014) are exceedingly critical of institutions that put pressure on staff in order to compete for public attention, arguing that such institutions are corrupting their researchers by eroding the criteria whereby success in science is judged and promoting publicity as a remedy for science. Marcinkowski and Kohring (2014:6) aver that, when public attention becomes a dominant criterion whereby science is judged, this is "not only alien to science, but indeed harmful to it". They state (2013:5):

> Once an institution has made the decision to compete for public attention, it is then bound (no matter what terms we use to embellish this or how respectable personal motives are) to the compulsion of self-promotion, of image building and image maintenance, of self-marketing, of consent management. But above all the criteria of success become ever more important for the generation of public attention. Science communication is therefore a gateway for non-scientific motives, relevance criteria and dynamics, and that, from the perspective of science, is anything but good news.

Furthermore, Weingart and Guenther (2016) point out that, when communication of scientific knowledge becomes persuasive in nature and biased by vested interests (as in the case of PR materials) it loses credibility. This may erode the credibility of science itself. Marcinkowski and Kohring (2014) highlight that institutionalised push communication, with its emphasis on gaining public attention via self-promotion and image-building, promotes non-scientific motives that may threaten the autonomy of science. Claessens (2014) contends that science PR is not genuine communication at all, since the element of interaction and dialogue with society is clearly lacking. In this regard, Edmeades (2009:36) writes, "[w]e can do public relations exercises for our institutions, but we scientists no longer adequately defend the values of truth, objectivity and impartiality."

Not surprisingly, PR practitioners claim that a PR approach will not necessarily taint science communication or detract from its credibility. For example, Dean (2009) argues that it is the job of the public information officer to nurture engagement between scientists and journalists and that this relationship building is all about trust.

By generating science news, Shipman (2014; 2015) argues, corporate communicators serve the needs of the organisation and also benefit scientists, the media and society. Furthermore, it is pointed out, journalists depend on institutional PR for news about science, and press releases initiate contact between scientists and journalists (Peters *et al.*, 2008). As such, PR people play a translational role and are a vital link between science and society (Cilliers, 2001).

While agreeing that a cautious approach to PR in the context of science would be wise, Irwin and Horst (2016) concur that science PR and persuasive communication are not intrinsically misguided or unethical. Instead, these authors argue, PR is one of many forms of communication in science that should be studied in terms of its practices and consequences. It may, they believe, even offer valuable lessons. The authors allege that, as far as public communication of science is concerned, it is often not possible to distinguish between science information, institutional messages and personally driven interests. They agree with Weingart and Guenther (2016) that universities no longer operate free of special interests, and argue that the same is true for research groups and even individual scientists. "For better or worse, universities and other state-funded research organisations have become aware of themselves as organisations in need of external support and legitimacy" (Irwin & Horst, 2016:3).

Similarly, Borchelt and Nielsen (2014:59) view PR in a scientific organisation as part of "managing the trust portfolio". University press officers also assert the benefits of PR efforts that result in science–media coverage. Citing a study by Phillips *et al*. (1991) about the influence of coverage in *The New York Times* on the citation rates of scientific articles, Shipman (2014) argues that media coverage benefits science by improving communication with the public, but also increases discovery of new work amongst scientists. Furthermore, Autzen (2014) provides evidence that increased media coverage of the research produced by a specific university is linked to the academic prestige of the institution.

It is certainly worth keeping in mind that good press officers care about their own professional reputations. As such, it would be counter-productive to oversell or hype up research findings, since journalists will soon lose faith in such communication materials and the people who issue it. One of the biggest challenges for press officers may be the ability to judge the quality and significance of the material presented to them by scientists within their own organisations (Peters *et al*., 2008b).

3.4.2.7. Institutional barriers

While a supportive institutional environment encourages public communication activity, the inverse is also true. In the absence of a clear institutional policy, researchers are uncertain about what constitutes public engagement, and they feel uneasy about spending time on external communication and media work (Gascoigne & Metcalfe, 1997; Holland, 1999; Edge *et al*., 2009). They may be hesitant to get involved if they feel that their employers do not value these activities (Andrews *et al*., 2005). Despite the evidence that institutions recognise the growing importance of public visibility as a way to gain support, institutions do not always encourage the communication efforts of individual scientists. On the contrary, institutional settings, culture and policies at times actively discourage scientists from public communication (Smith *et al*., 2013) and many research organisations have not yet normalised public communication as part of the organisational culture (Borchelt, 2001). A number of institutional barriers that constrain public science communication are discussed below.

The peripheral nature of public science communication: Arguably the biggest constraint in terms of scientists' involvement in public communication is the persistent perception that it is not an integral part of the responsibilities of a researcher and that spending time on public communication means neglecting the core research function (DiBella *et al*., 1991; The Royal Society, 2006; Ecklund *et al*., 2012; Watermeyer, 2015a). The academic promotion and tenure system prioritises peer-to-peer communication via scholarly journals and conferences, and does not recognise public communication as a legitimate form of scholarship (Jacobson *et al*., 2004).

Lack of recognition and reward: There is widespread consensus that a lack of official recognition limits scientists' involvement in public outreach (Dunwoody & Ryan, 1985; Miller, 1998; Treise & Weigold, 2002; Mathews *et al*., 2005; Vetenskap & Allmänhet, 2007; Jensen *et al*., 2008; Martín-Sempere *et al*., 2008; Peters *et al*., 2008b; Wigren-Kristoferson, 2011; Ecklund *et al*., 2012; Illingworth & Roop, 2015). Scientists also lament the lack of positive feedback from their managers (Van der Auweraert, 2008). These findings are echoed in a study of 40 European research institutions (Casini & Neresini, 2012), which led its authors to conclude that research institutions routinely fail to acknowledge public communication as an integral part of the research profession. Therefore, public communication remains a personal choice for many researchers (Bauer & Jensen, 2011) and institutional norms continue to present barriers that deter scientists from getting involved (Whitmer *et al*., 2010). Burchell *et al.* (2009:7) agree with the view that, at institutional level, public engagement activities continue to be seen as "under-incentivised and under-rewarded, potentially detrimental to research, and professionally stigmatising". Similarly, numerous surveys have highlighted that a lack of incentives or rewards for public communication continues to constrain scientists' involvement (Gascoigne & Metcalfe, 1997; Pearson *et al*., 1997; Gunter *et al*., 1999; Greenwood & Riordian, 2001; MORI, 2001; Andrews *et al*., 2005; Kim & Fortner, 2008; Besley

& Nisbet, 2013; Kreimer *et al*., 2011; Searle, 2011; Ecklund *et al*., 2012; Smith *et al*., 2013; France *et al*., 2015; McCann *et al*., 2015; TNS-BMRB, 2015; Namihira-Geurrero, 2016). In the absence of incentives to pursue public communication, scientists limit the time spent on these activities and rather focus on their laboratory or field work (McCann *et al*., 2015).

Lack of opportunities and training: One of the reasons why some researchers do not participate in public communication, is that they are unaware of opportunities and platforms that make it possible (or at least easier than otherwise) for them to get involved (Cilliers, 2001; Kaslow, 2015; Markowitz, 2017). Andrews *et al*. (2004) identify this as a major impediment and suggest that institutional outreach coordinators should provide timely information to scientists and provide support for their public engagement activities. Scientists cite the lack of training as a key reason why they do not know how to get started or lack confidence to get involved in public engagement (Worcester, 2002; Mathews *et al.*, 2005; Besley & Tanner, 2011; Ecklund *et al.*, 2012).

Academic autonomy: The flip side of the notion that scientists have a duty to communicate with the public, is the question whether they have the autonomy (or freedom) to do so, or not. This relates to the question whether scientists would need to seek approval from someone before talking about their work in public (Dudo, 2013), and also to the question whether scientists would ever be forced or coerced to communicate in public against their will. In order to control their image, some universities require their research staff members to obtain the necessary approval before speaking to the media, or may even try to prevent researchers from speaking about sensitive topics (Edmeades, 2009; Searle, 2011; Ndlovu *et al*., 2016). Such efforts to control public communication clash with traditions of academic freedom and autonomy and limit the ability of scientists to engage with external audiences (Peters *et al*., 2008b; Cribb, 2011). Some research organisations support favourable public communication, but try to restrict critical views, contested debate and reflexive dialogue. Respondents in an Australian survey (Metcalfe & Gascoigne, 2009:43) reported that their organisations sent out “mixed messages”, encouraging only “warm, fuzzy success stories”, but discouraging “anything that might be controversial”. Consequently, scientists may fear the internal perils they could face if they participated in public dialogue about controversial aspects of their research. Furthermore, Van der Auweraert (2008) points out that rules from funders or those who commission research, may also prohibit communication with public audiences. As can be expected, scientists who are free to speak in public and enjoy the support of their employers, are more likely to do so (Dudo, 2013; Dudo *et al*., 2014), while a lack of autonomy hinders their involvement (Davies, 2013). Marcinkowski *et al*. (2014) draw attention to the fact that levels of academic freedom and scientific autonomy vary sharply between countries. In South Africa, academic freedom is a constitutional right (Malherbe, 2006).

The case of Dr Mehmet Oz, a professor at the Department of Surgery at Columbia University, is an example of how scientists are protected by academic freedom in some countries. As a result of many controversial and scientifically dubious health claims made by Dr Oz on his television show, a group of 10 physicians, led by Henry Miller of Stanford University, wrote to Columbia University suggesting that it was unacceptable and damaging to keep Oz on as a faculty member. Citing their commitment to upholding the freedom of expression in public discussions for all faculty members, Columbia University refused to dismiss him (Pandey, 2015). By contrast, Ndlovu *et al*. (2016) report that politically sensitive research findings are censored in Zimbabwe, causing researchers to fear prosecution should they speak out about issues such as climate change and land reform.

3.4.2.8. Time constraints

Most scientists regard their academic work as more important than public communication, and constantly feel the pressure to publish in high-impact journals. The time demands of the academic world are probably the most significant force deterring scientists from public involvement (Smith *et al*., 2013; Crettaz Von Roten & Goastellec, 2015) and, despite viewing public involvement positively, it remains difficult for many scientists to accommodate public engagement within the demands of their academic careers (Burchell *et al*., 2009). Across a large number of studies, time constraints emerged as a major barrier to scientists' participation in public communication. Many scientists feel that it is too time-intensive and that they simply cannot afford the time (MORI, 2001; Andrews *et al*., 2005; Mathews *et al*., 2005; The Royal Society, 2006; European Commission, 2007; Poliakoff & Webb, 2007; Van der Auweraert, 2008; Kreimer *et al*., 2011; Searle, 2011; Allgaier *et al*., 2013b; Smith *et al*., 2013; France *et al*., 2015; McCallie *et al*., 2016; Namihira-Geurrero, 2016). In these studies, researchers point out that their teaching, research and administrative workloads leave little time for public communication, and that they see public communication as just one of many competing priorities. For example, 78% of respondents in a study of UK scientists mentioned time as a key barrier impeding public communication (TNS-BMRB, 2015). Clearly, in the highly competitive research environments of today, scientists are widely perceived to be overworked, with little time left for activities outside their academic duties. In this regard, Edmeades (2009:19) notes:

> Modern scientists are overloaded with work they despise: preparing proposals with all those make-believe costs and benefits, completing milestone reports, annual reports, reviews, etc. It is endless and there should be small wonder that there is little time or energy left to help the public.

A study by The Royal Society (2006) shows that research funders are aware of it that research grants provide a powerful tool for stimulating public engagement, but the funders are concerned about making additional demands on researchers. Similarly, Casini and Neresini (2012) argue that there is growing conflict between the increasing demand for public science communication and the traditional roles of scientists. Based on a review of public science engagement at higher education institutions in the United Kingdom, Watermeyer (2015b) agrees that organisational structures and institutional priorities at universities, in particular time-management systems, are significant barriers deterring academics from participation in public engagement. The author suggests that, due to its demands on researchers' time, public engagement may be fundamentally incompatible with the management frameworks in universities today.

Interestingly, however, a number of surveys reveal that time is not always a decisive barrier (Dang & Russo, 2015) and that many researchers would like to spend more time on public communication

(MORI, 2001; Dang & Russo, 2015; TNS BRMB, 2015). The study by Jensen *et al*. (2008) found that academically productive scientists are most active in terms of public communication. This raises questions over the validity of time constraints as a barrier towards public engagement. One could argue that, if scientists who do the most research and produce the most research articles have time to communicate in public, there is no reason why others cannot find the time to do so.

3.4.3. Evaluation practices

> ***Academic institutions and tenure committees must measure and reward time and effort devoted to outreach. And that, we're keenly aware, will require dedicated leadership and collective effort to change the culture of science.***
> *(Smith* et al.*, 2013:3)*

Evaluation can be considered a set of tools that are used to plan, monitor and measure an activity. Neresini and Pellegrini (2008:237) define evaluation as "establishing the extent, at least approximately, to which a given action has produced effects that match the purposes for which it was undertaken". They add, "evaluating is nothing other than learning from experience more systematically and more efficiently than when it is done spontaneously" (2008:238). In terms of the evaluation of public science communication, the authors note:

> Evaluation becomes a structured and formal activity, a systematic inquiry that applies specific procedures in gathering and analysing information on the content, structure and results of a project, programme or planned intervention.

Some leaders in the scientific world insist that public communication activities must be recognised and rewarded alongside academic outputs. For example, Leshner (2007:161) states:

> [...] the scientific reward system needs to support our colleagues' efforts to interact with the general public concerning their work and its implications. Funding agencies such as the Wellcome Trust and the U.S. National Science Foundation and National Institutes of Health have begun encouraging the scientists they support to include outreach efforts in their proposals. Academic institutions need to join in this chorus by rewarding faculty members who fulfill commitments to such work. That will entail putting public outreach efforts among the metrics used to decide promotion and tenure.

Universities around the world (also in South Africa[47]) have adopted engagement with society as part of its mission, but many still regard it as a low-priority task. In contrast to the status of research and teaching, community engagement is typically afforded meagre support (South African Council on Higher Education, 2010; Vetenskap & Allmänhet, 2011). Public science communication contributes to the so-called 'third-stream' activities, generally defined as follows (Molas-Gallart, Salter, Patel, Scott & Duran, 2002:iii):

[47] The 1997 South African White Paper on the transformation of higher education acknowledges community engagement as a core activity in higher education, and specifically calls on universities to demonstrate social responsibility and make expertise available to the broader community (South Africa Council on Higher Education, 2010).

> Third stream activities are concerned with the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments. In other words, the third stream is about the interactions between universities and the rest of society.

In the South African context, Nhamo (2013:129) shows that, while universities emphasise the importance of community engagement and outreach, these activities are neglected from a policy and investment perspective, and do not filter down to the job descriptions and performance agreements of researchers. The author states:

> For community engagement to find its rightful space … it needs to be benchmarked, measured, monitored and verified as well as evaluated and recognised just like teaching and learning as well as research.

In the absence of formal evaluation, scientists perceive that public engagement is not an official expectation from their employers (Watermeyer, 2015b) and consequently they remain uncertain about whether their public communication efforts will yield any professional rewards (Liang *et al*., 2014). Neresini and Pellegrini (2008) agree by stating that failure on the part of research organisations to incorporate evaluation into public science engagement indicates that these organisations rate such activities as marginal. Conversely, when research institutions evaluate public science communication formally, it signals that these activities are valued and demonstrates its organisational status (Dunwoody *et al*., 2009; Neresini & Bucchi, 2011).

Not only institutions, but also scientists themselves, often think of public communication as informal and voluntary activities and consequently they do not see the need for evaluation of their own activities in this sphere (Holliman & Jensen, 2009). Scientists are uncertain about what constitutes success in public engagement and which criteria and indicators could be used to assess these activities (Grand *et al*., 2015).

If one accepts that researchers need incentives to encourage their involvement in public communication, it implies that a clear and evidence-based system for measurement and rating of public engagement activities is required to change views about the centrality of public communication to research (Vetenskap & Allmänhet, 2011). For example, O'Brien and Pizmony-Levy (2016) suggest that community engagement should be used in combination with traditional indicators of academic performance (e.g. publications, citations, awards) when researchers' contributions to their institution and society are measured.

Importantly, an evaluation system must be relevant to the specific setting. This means that, for South Africa, such an evaluation system should be tailor-made for higher education institutions that operate in a diverse and unequal society, characterised by pressing developmental needs and socio-economic challenges (South African Council on Higher Education, 2010).

Research literature that focuses on the evaluation of public science communication is sparse, and evaluation of public engagement at universities have been largely neglected, with relevant reports mostly limited to grey literature (e.g. Hart, Northmore & Gerhardt, 2009). This could be the result of a general lack of evaluation expertise in the science communication community (Rowe & Frewer, 2000; 2004; Rowe *et al.*, 2004), but it could also be caused by a lack of interest and investment in doing proper evaluations (Neresini & Bucchi, 2011). Notably, the nature and diversity of public science communication make it particularly challenging to evaluate these activities (Godin & Gingras, 2000; Burns *et al*., 2003; Sánchez-Mora, 2016).

Consequently, public communication continues to exist as an informal activity, done for the public good and "not based or evaluated on any established indicators or standards" with vague ideas around what constitutes success (Neresini & Bucchi, 2011:64). As a result, most research institutions still lack a culture of public engagement where these activities are properly recognised, evaluated and rewarded, and where the activities count when funding and promotion decisions are made. Even countries where the importance of public science engagement is widely recognised, rarely use formal indicators to evaluate the consequences of these activities (Vetenskap & Allmänhet, 2011).

Given the growing recognition of public science communication in achieving influence beyond academia, several scholars scientists (Moore & Ward, 2008; Baron, 2010a,b; Smith *et al.*, 2013; Grand *et al.*, 2015) have urged the science community to reconsider its measures of scientific success. These authors argue that public communication should become an integral component of a scientific career, and that it should be included in the performance reviews of university-based.

3.4.3.1. Evaluation and public communication behaviour

Proper evaluations that count towards career advancement would motivate scientists to invest time and effort in these activities. Many scientists indicate that they would value consideration of public engagement activities as a merit when their professional activities are formally evaluated (The Royal Society 2006; Moore & Ward, 2008; Kreimer *et al*., 2011; Torres-Albero *et al*., 2011; Ren *et al*., 2014).

However, when public science communication is evaluated formally, for example as part of research grants, this could imply that public communication activities will be expected of all those who receive such grants. Under these conditions, public science communication would no longer be a choice, but another obligation that researchers must fulfil. This implies not only a loss of autonomy, but also adds to the administrative workload of scientists. In particular, scientists who work in complex and abstract fields of research argue that it would be hard for them to demonstrate regular and meaningful public communication. They suggest that it would not be reasonable or practical to make public communication a compulsory component of every research grant (Pearson, 2001). Therefore, some scientists oppose the idea of evaluating public science communication, and prefer to do public communication as a voluntary activity, giving them control over their own commitment (Grand *et al*., 2015; Chikoore *et al*., 2016).

3.4.3.2. Evaluation challenges

While indicators for the evaluation of teaching and learning have largely been standardised, this is not the case for the field of public science engagement (Hart & Northmore, 2011; Favish, 2016). Fields such as bibliometrics and scientometrics focus entirely on the study of science outputs within the academic environment, with large databases registering scientific journal publishing and its associated consequences. Since the outputs and outcomes of public science communication are not registered, indexed and catalogued in the same way (Kyvik, 2005; Bentley & Kyvik, 2011), efforts to evaluate public science communication remain largely ad hoc or of poor quality, and are typically characterised by low investments (Edwards, 2004; Rowe, Horlick-Jones, Walls & Pidgeon, 2005; Wilkinson, Bultitude & Dawson, 2011; Jensen, 2014). As a result, vigorous quantitative and qualitative research data on the effects of public outreach is scarce. This makes it difficult to demonstrate the value of such data, to convince research managers of its importance and to motivate researchers to participate (Casini & Neresini, 2012).

Scholars admit, however, that the outcomes of and responses to public science communication are not easy to study (Burns *et al*., 2003). Such outcomes and responses happen in societal settings, and not in controlled laboratory environments. They require specialised social science expertise, and their aims are broad and long-term in nature. Consequently, they are problematic to quantify and measure. Existing indicators in this field typically focus on quantifiable outputs, such as media coverage statistics or the size of event audiences, while ignoring the less tangible, but arguably more important outcomes (Pearson, 2001; Burns *et al.*, 2003; Storksdieck & Falk, 2004; Neresini & Pellegrini, 2008).

In order to evaluate public science communication activities meaningfully, it is necessary to develop relevant evaluation tools and strategies (Holland, 1999; Moore & Ward, 2008). Evidence is emerging that research funders and higher education institutions are taking note of the new public roles of their research staff, and are working towards systems that will recognise and reward the scholarship of engagement (Driscoll & Sandmann, 2016). The Carnegie Foundation for the Advancement of Teaching has developed new ways to classify and document community engagement activities in higher education (Driscoll, 2009). Moore and Ward (2008) show how scientists could compile and present engagement dossiers that showcase their contributions. A Swedish research council (Vetenskap & Allmänhet, 2007; 2011) has developed a comprehensive set of indicators that could be used to measure public outreach activities of individual scientists and research institutions, while a group of UK universities has developed a system of indicators suitable to evaluate so-called ‘third-stream activities’ (Molas-Gallart *et al*., 2002).

The United Kingdom has made strong efforts to support public science engagement based on a solid evaluation framework. In 2008, six UK universities were recognised as ‘Beacons for Public Engagement’ (and awarded considerable funding), in an effort to change university culture in favour of public engagement (Research Councils UK, 2014). Subsequently, a National Coordinating Centre for Public Engagement (NCCPE) was established to coordinate and streamline support and capacity building. The NCCPE has compiled a guide for university administrators and academics to help them with the monitoring and evaluation of public engagement (Hart *et al.*, 2009). In 2010, Research Councils UK (the corporate unit of the seven individual UK research councils which are the major research funding bodies in the United Kingdom) launched a concordat for engaging the public with research, aiming to embed public engagement within universities and research institutes (Research Councils UK, 2017). This agreement outlines expectations, responsibilities and commitments regarding public science engagement, including the principle that researchers are recognised and valued for their roles in these activities.

Public science engagement similarly emerges as a key thematic element of European Commission research funding. The Public Engagement Innovations for Horizon 2020 project was designed to identify, analyse and refine innovative tools that could be used for responsible governance of research and innovation, including defining criteria for success, and developing a toolkit to evaluate public engagement activities (Rask, Mačiukaitė-Žvinienė, Tauginienė, Dikčius, Matschoss, Aarrevaara & Luciano, 2016).

Notably, Burchell (2015) discusses the increased significance of public engagement in funding proposals, but also point to evidence that panel members who review funding applications may not be taking this criterion seriously, meaning that even when scientists do not present any evidence of public engagement plans or activities, they may not be penalised by the reviewers. The same author also refers to studies showing that researchers themselves have serious reservations about the meaningful measuring and evaluation of public engagement activities.

3.4.4. Medialisation

> ***Academia should (also) prevent the scientific rationale from colonization by the logic of public attention, instead of turning scientists into accomplices of mediatization.***[48]
> *(Marcinkowski & Kohring, 2014:6)*

Medialisation of science refers to the increasing centrality of the media to research, affecting both scientists and the organisations where they work (e.g. Weingart, 1998; Rödder, 2011; Peters, 2012; Ivanova, Schäfer, Schlichting & Schmidt, 2013; Weingart, 2017a). It may cause scientists to present themselves in specific ways, prioritise topics and choose research methods with maximum media appeal in mind. Its effect on research organisations may be an increased investment in science–media relations. These medialisation effects may be enhanced as science becomes more competitive and dependent on public and political support. As a result, media criteria become relevant within science and start to affect the way science is done, thereby posing a threat to the autonomy of science (Marcinkowski & Kohring, 2014).

Already two decades ago, Weingart (1977) expressed concern about the potentially problematic repercussions that changing norms of knowledge production, as manifested in medialisation, present for science. The author argues that emphasis on the application of knowledge, rather than

[48] Marcinkowski and Kohring (2014:5) describe 'mediatization' as "the adaptation to the criteria of public attention" and "a PR strategy to enable universities to survive and thrive in an artificial competition for financial resources that was initiated in the political domain". This is similar to the concept of 'medialisation' defined by Weingart (1998:872) described as a "science–media coupling" or an increasing orientation towards the mass media, with the consequence that media criteria become relevant within science (Peters *et al*., 2008).

the search for the basic laws of nature, has made knowledge production "socially accountable and reflexive" (1997:593), and therefore subject to social, political and economic criteria when it comes to quality reviews. The mass media, Weingart (1997) believes, play a significant role in this process of legitimisation, causing scientists to reconsider the type of research they undertake, potentially favouring topics and research designs with media appeal. Scholars have noticed that, from time to time, scientists themselves are also guilty of hyping up research and making exaggerated claims for the sake of funds and media attention (Weingart, Engels & Pansegrau, 2000). Goodell (1977:132) relates how scientists, when given an opportunity to review press releases, "sometimes encourage the huckstering, helping to sell themselves, their institutions, or the scientific enterprise". When public prominence is regarded as a more important as an indicator of status compared to scientific reputation, this ultimately endangers scientific autonomy and thus also research quality (Weingart & Pansegrau, 1999).

Medialisation is fuelled by scientists' need for political support, intensified competition for research resources and growing demands for organisational legitimisation as a result of a new governance of science (Dunwoody *et al*., 2009). As a result, scientists vie for media attention by issuing exaggerated warnings and announcements (Weingart, 2002), and research groups exploit the media in order to compete for political support via the practice of "science by press release" (Rödder, 2009:460).

Marcinkowski and Kohring (2014) highlight the medialisation of research institutions as particularly problematic and damaging. This kind of science communication is not driven by a desire to allow the lay public to participate in science, but rather by political and financial rivalry between institutions. The danger of this kind of communication is that it confuses visibility with relevance, the authors warn, and the currency of the news media becomes the dominant currency in science. Consequently, Marcinkowski and Kohring (2014:5) claim the following about medialisation:

> It exercises a strong influence at least on the entire process leading to understanding in science: research topics are chosen according to their current potential for attention, resulting in a mainstreaming of scholarly work. Hypotheses are formulated according to exactly the same criteria. Putative research 'findings' are published through the mass media before having passed the peer review process. Results are reframed for the public in order to make positive aspects more salient while hiding critical consequences. The social impact of any field of research is consequently exaggerated. Research money and other rewards are distributed to those who master the 'beauty contest', and therefore this process is reinforced. In effect, academics and their work are evaluated according to whether or not they capture the attention of a non-academic public sphere.

While the concept of medialisation was only introduced in the 1990s (see Weingart, 1998), scholars have been reflecting on the escalating influence of the mass media on science before that. Two classic science communication books from the 1970s and 1980s respectively, hint at changing relationships between science and the media: *The visible scientists* (Goodell, 1977) and *Selling science* (Nelkin, 1987). Goodell writes about how anticipated media responses influence the way scientists present themselves and their work in public, adding, "… it seems that the 'discovery' approach of the press is pressuring some scholars to design neat, quick experiments to accommodate the press" (Goodell, 1977:123). Nelkin highlights how the science community moves away from tentative replies to media enquiries in favour of pro-actively seeking publicity and taking control of the public image of science, based on the belief that public visibility is strategically important to sustain a favourable public image of science and to ensure ongoing public support.

3.4.4.1. Evidence for the medialisation hypothesis

Evidence in support of Weingart's medialisation hypothesis emerged from various studies. Work done by Borchelt (2008), Engwall (2008), Rowe and Brass (2011), Rödder (2012) and Kohring *et al*., 2013) demonstrates how research institutions intensify their external communication efforts and focus on communicating research results to the media in order to promote their reputations. These studies underline that management teams in universities increasingly value media visibility and, consequently, that university PR is driven by the urgency to attract positive (and minimise negative) publicity. Therefore, universities appoint professionals who know how to cultivate good relationships with journalists and who can provide communication expertise to support scientists' media interactions. Furthermore, these universities instruct academic staff to make their expertise available as commentators in the mass media and to communicate their research achievements and expertise pro-actively. Autzen (2014) shows that prestigious universities are particularly active at issuing science press releases, and the media attention seems to have the desired effect. For example, Allgaier *et al.* (2013b) demonstrate that German and American neuroscientists whose work was featured in the media gained a competitive advantage in their organisations, and that this also increased their chances of getting access to external funding.

Based on a case study of biomedical scientists in Germany, Peters *et al.* (2008) conclude that the research team was not able to show direct empirical evidence of medialisation, but they did demonstrate the political effects (associated with efforts to legitimise science by demonstrating its relevance to the public) of media visibility. Similar to earlier studies, Peters *et al.* (2008) discuss how media orientation guides institutional PR strategies, increases the value accorded to science-related media efforts, and leads scientists to adopt media logic for self-preservation. They conclude that the effects of medialisation propel the visibility and uptake of scientific expertise in policymaking.

From a study of the media coverage of genome research, Rödder (2009:452) found that this field is "indicative of the medialisation of science", based on the observation that media attention peaks resulted from multiple press conferences and other media events instigated by the research teams in order to exploit media interest. She concludes that the effect of the media logic and news values is evident in the way the research is presented, which follows the criteria of the media, rather than those of the science system.

Marcinkowski *et al.* (2014) provide further evidence that scientists interact with the media frequently and comply with media requests when they perceive that their universities desire media visibility. The authors conclude that PR is now firmly entrenched within scientists' public communication activities and that most scientists have a closer relationship with university PR staff than with journalists.

For the purpose of studying how neuroscientists use new media channels within the context of medialisation, Koh *et al.* (2016:175) focused on the effects of medialisation on individual scientists. The authors define it as "self-reported changes in scientists' approaches to media, which include increased attention to and adaptation of media criteria in their work, as well as an increased adoption of media channels for communicating with the public". The findings by Koh *et al.* (2016) suggest that scientists believe that social media are influential in promoting public visibility and enhancing funding opportunities. Interestingly, scientists attached the highest value to getting their work featured in the *New York Times*, perceived as a "legacy channel" (Koh *et al.,* 2016:189), to which the authors refer as "the holy grail of medialisation" (Koh *et al.,* 2016:170). The authors suggest that this may cause scientists to consider the criteria of this specific newspaper in their own research.

However, despite substantial evidence of the effect of medialisation on how science is done and communicated, some scholars question whether its effects are universal, and also point to counter-effects. Medialisation varies according to the research field. Research that is closely linked to everyday life, such as health research, is influenced by medialisation to a greater extent compared to fields such as mathematics and physics (Rödder, 2009). Senior researchers may be more susceptible to medialisation than their younger colleagues (Ivanova *et al*., 2013). Furthermore, medialisation effects may be cyclical, with significant variations over time (Schäfer, 2009; Rödder & Schäfer, 2010) and between countries (Lo & Peters, 2015).

3.4.4.2. Ways in which scientific journals contribute to medialisation

The practice of scientific journals to issue press releases on some of its articles, boosts the media coverage of the selected articles (De Semir, Ribas & Revuelta, 1998). This leads to concerns that scientific journals have become caught up in the commercialisation of science and the competition for attention, leaving science journalists in doubt about which sources to trust (Allan, 2009). Importantly, Franzen (2012) provides evidence of the tendency of prominent scientific journals such as *Science* and *Nature* to select manuscripts on the basis of their potential to attract media attention, rather than on scientific merit.

3.4.5. Summary and implications from the literature review

The literature review confirmed that a multitude of factors influence scientists' public communication behaviour. There are three main clusters of factors: **background factors** that are inherent to the individual researcher, **attitudinal factors** that shape how researchers feel about communicating in public, and **contextual factors** that relate to the national or institutional environment where researchers work.

3.4.5.1. Summary of literature on background factors

There are good reasons to expect that scientists' public communication behaviour will be shaped by their field of research. Some topics are close to everyday life and resonate with media preferences.

Accordingly, the literature shows that, due to distinctive variances in the normative structures, degree of codification, societal resonance and cultural features between scientific disciplines, scientists who work in different fields of research have diverse views and experiences of public communication of science.

It is evident that **highly productive scientists** are also the most active in terms of public science engagement. The status and outputs of these scientists fuel media and public interest, and they typically know how to use the media to gain attention and influence.

In terms of the influence of **age** and **experience**, a range of studies reveal that scientists across different age brackets and career stages hold different views about the public and the value of public science communication. In general, scientists gain communication confidence as they get older, and they become less concerned about negative responses from peers. Older and younger scientists prefer different types of communication activities, with older scientists generally favouring media interactions, and younger scientists more willing to experiment with new media and social networks.

Research findings about the influence of a scientist's **gender** on public science communication are inconclusive, but it is clear that men and women face different normative influences, expectations and barriers that shape their involvement.

While the science communication literature neglects to consider **population group** as one of the background factors that could influence a scientist's public communication behaviour, this factor could be relevant in the South African context. Given the perceived importance of role modelling as a way to attract young people to careers in science, and the fact that South Africa's population is more than 80% black[49], it is considered essential to understanding the factors that influence if, why and how black researchers communicate in public.

3.4.5.2. Summary of literature on attitudinal factors

The literature study confirms that **the norms of science** exert a powerful influence on public communication, but that scientists comply with these to varying degrees. When scientists defy the norms of their profession, they may be subject to intense peer scrutiny and criticism, and face professional penalties. However, norms are not static and scholars agree that the science community is becoming more tolerant towards public communication, largely as the result of a growing awareness of the importance of nurturing public and political support for science.

The **public audiences** with whom scientists engage are diverse and multi-faceted, and increasingly expect to be active participants in science debates and decisions. Despite a generally negative view of the public, scientists are increasingly aware of the need to reach out and involve people in constructive dialogue about the societal implications of cutting-edge science. There is a general

[49] According to mid-year population estimates from Statistics South Africa (Stats SA, 2016), South Africa's population of close to 56 million people consists of 80.7% African, 8.8% Coloured, 8.1% White and 2.5% Indian/Asian people.

expectation that tensions between science and society will intensify as emerging innovations from fields such as synthetic biology, nanotechnology and epigenetics continue to pose more vexing social, moral, ethical and political dilemmas. Public controversy has become a feature of current science, ensuring that science is seldom far from the public limelight. The stage is set for scientists to play an ever more prominent role in public debate.

Historically, many scientists have had disapproving **attitudes towards public communication of science,** and often judge their peers who spend time and effort in the public arena harshly. At the same time, many leaders and influencers in the science arena have defended the value and virtues of public science engagement and encouraged researchers to interact with the public. Today, scientists continue to view and value public communication differently. For some, it is a core part of their scholarly identity. Others view it as a marginal activity that they may choose to embrace or ignore. Large-scale surveys in a number of countries indicated that scientists are generally becoming more favourably inclined towards public communication, and that more scientists are taking part with increasing frequency. Scientists' attitudes towards public communication are shaped to a large extent by their own communication objectives.

Historically, the relationship between **scientists and the traditional media** has been problematic, fuelled by normative and cultural clashes between scientific and journalistic professions. However, both scientists and journalists stand to benefit from collaboration: journalists get access to science news and expertise, while scientists gain potentially valuable attention for their work. While some scientists remain ambivalent about working with the media, recent research indicates that science–media relationships are improving.

Digital media and social networks have fundamentally changed the communication landscape, and provide a new research perspective on scientists' communication behaviour. Researchers wish to understand if and how scientists use social media and what results from that. Evidence is emerging that social networks can be a powerful communication tools for enhancing both public and academic visibility. Scholars highlight a multitude of benefits and risks in terms of communicating science online, but generally agree that the influence of digital media will continue to grow and that its influence cannot be ignored.

When leaders in the scientific world call on scientists to engage the public, they often remind scientists that they owe a **moral duty** to the public. Most scientists (but not all) agree, and this motivates their efforts to engage with society. They may also feel a moral duty to help improve quality of life through active engagement, particularly in developing countries. Some social scientists are sceptical about whether scientists who step out in public life, and the institutions which support them, are truly motivated by a sense of duty, suggesting that such scientists are rather motivated by self-interest. This is evident when research organisations, eager to protect their image, prevent scientists from speaking out about controversial or sensitive research topics.

Scientists' perceptions of their own communication skills, i.e. **self-efficacy**, influence their participation in public communication. Despite the view that most scientists struggle to communicate effectively with lay audiences, scholars agree that scientists are able to improve their communication competencies via training. A wide (and growing) range of training opportunities are on offer for scientists who want to equip themselves with communication skills and confidence.

Scientists, like everyone else, have different **personality types**, ranging from shy introverts (the stereotypical scientist) to outspoken extroverts (the typical visible scientist). While personality type clearly has a bearing on the willingness and interest to communicate in public, this link has rarely been investigated empirically. Given the range of personality types, many scientists feel that it would be unfair to demand public communication of all scientists. Others argue that introverts should simply find different ways to engage.

There is widespread agreement that, for some scientists, public engagement offers a wide range of intrinsic **rewards.** These rewards range from pure enjoyment and personal satisfaction, to new meaning and inspiration for their research. Visibility also brings tangible benefits, such as money, collaborators, citations and students. Some scientists are motivated by these rewards towards communication, but others remain unconvinced that public science communication will benefit them personally or professionally.

In addition to overcoming some of the practical and systemic barriers that make it difficult for scientists to communicate their research in public, some scientists have to overcome their own concerns regarding public visibility. These **fears** are mainly normative in nature, and therefore related to the potentially negative impact on their careers. Scientists may have concerns about working with the media or using new media, while commercial research agreements and political sensitivities may limit their ability to speak publicly about their work.

3.4.5.3. Summary of literature on contextual factors

Despite the universal nature of science, communicating science to public audiences is shaped by the political and cultural differences across regions of the world, and will therefore be characterised by the **national context**. In some countries, public communication of science is encouraged and supported at legislative and policy level. The organisational and media infrastructure that facilitates interactions between scientists and public audiences also differs between nations. It is particularly complex and challenging to communicate science in culturally diverse societies and developing countries.

The **institutional environment** influences public science communication. While some institutional influences encourage scientists to get involved, there are also disincentives. Furthermore, there is some reason for concern over the motivations and objectives that drive institutions to invest in public science communication.

In order to include public communication of science in scientific reward systems, the science community would have to accept it as a legitimate scholarly activity. The next challenge is to find ways to track and **evaluate scientists' public communication efforts**, so that they can be included in the metrics used to evaluate scientists for promotion and tenure. The difficulties of developing suitable indicators to evaluate public communication may be one of the main reasons why research organisations hesitate to include public communication activities in their formal evaluations of the performance of their research staff. However, it is inevitable that the development of suitable evaluation tools to measure public science communication will develop further as research funders increasingly require of scientists to provide evidence of their public science communication efforts. While some research evidence shows that many researchers would be in favour of more formal evaluation of public science communication, there are equally those who oppose this idea.

Scholars have provided empirical evidence for the influence of **medialisation** via media attention (growing interest from the media to report on science) and media orientation (escalating efforts on the part of science organisations to compete for the attention from the mass media). Concerns about how medialisation influences scientific research and public science communication relate to its potential effect on the credibility and autonomy of science.

3.4.5.4. Implications

Existing studies into the factors that influence scientists' public communication behaviour were found to be predominantly quantitative in nature, and did not focus on researchers currently living and working in South Africa. Consequently, it was considered necessary to explore, via an in-depth qualitative study, how the background, attitudinal and contextual factors discussed above influence the public communication behaviour of scientists in South Africa. This would locate the study within the context of local societal challenges and institutional culture.

Furthermore, while several scholars have explored cross-country differences in public science communication, virtually no research has been done to see whether a researcher's population group has any effect on her/his communication views and/or behaviour. This question, whether population group affects scientists' public communication behaviour, was therefore included in the current study.

Chapter 4: Research design and methods

In this chapter, I provide an overview of the empirical components of this study, which consisted of the following two phases: an email request to a panel of science-media experts (journalists, educators and media industry professionals, who work at the interface between science and the public) to identify publicly visible scientists currently living and working in South Africa, and in-depth, qualitative interviews with 30[50] of them. Where necessary, additional information about individual researchers, for example their NRF rating status, were obtained using desk research.

4.1. Using science-media experts to identify visible scientists

In a qualitative study, selecting the most appropriate group of scientists to interview presents a pivotal challenge to researchers. My approach of targeting visible scientists was based on a seminal study conducted by Rae Goodell in the United States during the 1970s,[51] for which she was awarded a PhD from Stanford University (Goodell, 1975). After considering various options for identifying visible scientists (such as media content analysis, selecting winners of prestigious science prizes, and public opinion surveys), Goodell concluded that asking a panel of science-media experts (including journalists and journalism educators) offered "the best combination of accuracy and feasibility" and that it was "an effective choice" (Goodell, 1975:446). She pointed out that using a panel of respondents, each with their own experiences of scientists interacting with the public, allowed the researcher to draw indirectly on a number of indicators of visibility. She added that it was important to choose a panel representing a broad range of expertise, but consisting of people who worked in some way as liaisons between scientists and the public, since this would imply that they were in a position to monitor the flow of information between scientists and public audiences. Goodell's panel consisted of 31 members, representing newspapers (9), magazines (7), wire services (3), broadcasting (3), academia (6) and book publishing (3).

After identifying 45 visible scientists, Goodell selected eight for special attention in her study (Goodell, 1975). They were Barry Commoner, Paul Ehrlich, Margaret Mead, Linus Pauling, Glenn Seaborg, William Shockley, BF Skinner and Carl Sagan. Goodell showed that these scientists became public figures primarily via the mass media.

Despite current changes in the media landscape, the mass media play a decisive role in making individuals publicly visible. Furthermore, modern print and broadcast media outlets have digital platforms, and therefore journalists who work in the mass media are typically active on digital media platforms. Therefore, I followed Goodell's approach for identifying the most visible scientists in South Africa, namely to consult with a panel of experts at the science-media interface. This approach

[50] See Appendix 5 for the list of 18 South African scientists who were mentioned by four or more members of the science-media panel, and Appendix 6 for the list of scientists interviewed for this study.

[51] Goodell's dissertation (published in 1975) and her book (published in 1977) had the same title: *The visible scientists*.

was deemed to be the most feasible and effective, and also allowed me to draw on a number of visibility indicators via the experiences of the panel members.

I used purposive sampling to identify the science-media experts whom I could approach for this study. On the topic of purposive sampling, Babbie and Mouton (2001:166) explain that it may be appropriate to select a sample on the basis of one's own knowledge of a population, while Bryman (2012:418) states, "the goal of purposive sampling is to sample participants in a strategic way so that those sampled are relevant to the research questions that are being posed". Similarly, Palys (2008:697) notes that purposive sampling is "virtually synonymous with qualitative research" and that it involves "a series of strategic choices about with whom, where, and how one does one's research".

My selection of science-media experts was therefore based on my experience of 25 years in the local science communication environment. I included full-time and freelance journalists who were known to me as actively reporting on topics related to science, health and the environment. I also included South African scholars in the field of science communication, journalism and media studies. I did not include any institutional (university- or science council-based) communicators in order to avoid bias in favour of visible scientists at specific research organisations.

I contacted the science-media panel members via email,[52] and asked them to help me identify scientists, currently living and working in South Africa, whom they regarded to be visible in the public sphere. Following the approach used by Goodell (1975), I kept the request to the panel members brief and simple in order to encourage responses. I used Twitter to remind panel members of my request. The respondents were advised that I would list their names in my study, unless they had any objections, but that I would not associate the names of panel members with specific scientists identified during this phase of the study.

The science-media panel consisted of 63 members, and 46[53] of them (73%) responded to my request by sending me names of scientists whom they perceived to be publicly visible in South Africa. All of the 46 respondents agreed to be identified in this study. This consultation took place during November and December of 2016. A total of 211 individual scientists currently living and working in South Africa were identified as publicly visible by this panel. In total, 367 names were suggested, representing 211 individuals once duplicate mentions had been removed. Given that the maximum number of names expected if each respondent listed ten scientists would be 460, the list of 367 names represented 80% of the expected maximum.

The 211 visible scientists identified by the panel, represented less than 1% of the research workforce in the country. According to 2014–2015 statistics (Stats SA, 2016), South Africa had 25 300

[52] The text of the email sent to the science-media panel members is included in Appendix 2.

[53] The science-media panel respondents are listed in Appendix 3.

researchers at the time (excluding doctoral students and post-doctoral fellows at higher education institutions).

Only 46 of the 211 scientists were mentioned by two or more panel members. This meant that 165 scientists (78% of the total) were mentioned by only one person on the science-media panel. The 'top 18' (i.e. scientists who were mentioned by four or more panel members) are listed in Appendix 5. Mentioned by 27 members of the science-media panel, Professor Lee Berger, a paleoanthropologist at the University of the Witwatersrand, emerged as the most visible scientist in South Africa at the time of this study (2016–2017).

4.2. Profile and characteristics of selected scientists

From the 211 scientists identified by the science-media panel as publicly visible, I selected 30 scientists to interview. Firstly, I targeted the 18 most visible scientists identified in the current study. One was not available and one was retired, so I eventually interviewed 16 of them. The remaining 14 scientists were all selected from the group of 211 scientists, but, given that the most visible scientists were dominated by white males in the natural/physical sciences, I opted to include more black women and social scientists.

In Appendix 6, I provide a detailed breakdown of the publicly visible scientists currently living and working in South Africa who were interviewed for this study (n = 30) according to research field, institution, population group, gender and year of birth. Interviewing a total of 30 scientists was deemed to be feasible, affordable and appropriate. This number of interviewees compared well with earlier studies of a similar nature. Van der Auweraert (2008) interviewed 15 researchers (at one university) for her PhD study looking at the science communication behaviour of scientists in Belgium. Burchell *et al*. (2009) interviewed 30 scientists in their UK study of communication culture amongst professional scientists. Horst (2013) interviewed 20 scientists for her Danish study on scientists' perceptions of representing research in public.

4.2.1. Visible scientists in terms of South Africa's science workforce

Only 211 (or less than 1%) of the 25 300 researchers in South Africa at the time of this study (Stats SA, 2016) were identified as publicly visible in the current study. This implies that, as has been shown in other countries (i.e. Kyvik, 2005; Bentley & Kyvik, 2011; Jensen, 2011), a small minority of scientists in South Africa take on a disproportionate responsibility for public science engagement in the country.

4.2.2. Gender balance of visible scientists

The latest statistics on the male to female ratio in the local scientific workforce showed a split of 55.7% male to 44.3% female (DST, 2015). Men were even more dominant amongst the group of 211 visible scientists identified in the current study, with 133 (63%) men and 78 (37%) women. Similarly, 11 (61%) of the 18 most visible scientists were men.

There were only 17 black women (8% of the visible group) amongst the total group of 211 visible scientists. I therefore opted to include more women from the total sample of 211 visible scientists in order to achieve a better gender balance in the interviewee group. The visible scientists interviewed for this study consisted of 16 women and 14 men. Consequently, it was possible to solicit views more or less equally from both genders about whether they considered gender to be a factor that would make a difference when scientists communicated in the public arena.

4.2.3. Age distribution of visible scientists[54]

The age distribution of the full sample of 211 visible scientists identified in the current study is not known, but I used desk research to determine the year of birth of the 18 most visible scientists in South Africa identified in this study, while I also confirmed the year of birth of the 30 interviewees at the end of each interview.

The most visible scientists (i.e. those mentioned by four or more of the science-media experts and listed in Appendix 5; n = 18) were born between 1947 and 1971. Therefore, on their birthdays in 2016, their ages ranged between 45 and 69 years, with an average age of 52. Only two people in this group were younger than 50. The age distribution of the most visible scientists identified in this study was not surprising, since it takes time to achieve public visibility (Goodell, 1975) and older scientists are generally more actively involved in public communication (Kreimer *et al*., 2011; Crettaz Von Roten, 2011). Furthermore, senior scientists are better able to deal with the potentially negative responses that may result from public visibility (Bauer & Jensen, 2011; Chikoore *et al*., 2016).

My interviewee group (n = 30) were born between 1949 and 1980, and included six scientists younger than 50 at the time of the interview. Their ages ranged from 36 to 66 years old, with an average age of 55 at the time of being interviewed. Interviewees were not selected for age, but the age distribution over 30 years made it possible to solicit opinions across a wide range of age brackets. Interviewees are listed according to biographical details, including year of birth, in Appendix 6.

4.2.4. Visible scientists per population group

White people constitute only 8.1% of the South African population (Statistics South Africa, 2016), but white scientists constitute 58.5% of the current scientific workforce of the country (DST, 2015). In the current study, 164 of the 211 scientists identified as being publicly visible (or 78% of the visible group) were white. Black[55] researchers in South Africa constitute 41.5% of the scientific workforce, but only 47 black researchers (22% of the group of 211 visible researchers) were identified as publicly visible.

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[54] In order to compile an age profile of the visible scientists I interviewed, I asked them for their year of birth during the interviews.

[55] Black researchers = consisting of African, Coloured and Indian researchers.

The results of this study showed that about 1% of the white scientists in the country were deemed to be publicly visible by the science-media panel (164 out of 15 775), compared to only 0.38% (47 out of 12 236) visible scientists amongst black researchers. The group of 18 most visible scientists (see Appendix 5) consisted of 11 white and 7 black scientists. These statistics illustrate the proportional underrepresentation of black scientists in the South African scientific workforce, as well as amongst scientists who are visible in the public sphere.

4.2.5. Visible scientists in the study according to nationality

The visible scientists identified in this study, were all living and working in South Africa at the time of being interviewed. Of the 30 scientists, 27 were South African citizens by birth. Professor Don Cowan was born in New Zealand, but moved to South Africa in 2001 and holds dual citizenship. Having moved to South Africa in 1990, Professor Lee Berger also has dual citizenship (American and South African). Professor Tolullah Oni moved to South Africa in 2007. She is a Nigerian citizen, but has permanent residency in South Africa.

4.2.6. Visible scientists per research field

The split of visible scientists identified (n = 211) according to broad research field (Table 4.1) showed that natural scientists, social scientists and health scientists dominated, with fewer researchers working in the hard sciences and engineering. The 64 visible scientists in natural, biological and agricultural sciences included 8 researchers in the field of palaeontology. The combined disciplines of social sciences, humanities and arts accounted for the second biggest group, followed by health sciences, physical sciences and environmental sciences. Only 12 engineers (6% of the 211 visible scientists) were identified as being publicly visible.

Table 4.1: The number of visible scientists in South Africa per research field

Broad fields of research	**Number**	**%**
Natural, biological and agricultural sciences (animals, plants, microbiology, conservation, ecology, marine biology, biotechnology, genetics, agriculture, food security, palaeoanthropology)	64	30.33%
Social sciences, arts and humanities (education, communication, media studies, history, economics, political sciences, law)	50	23.70%
Health sciences (HIV/Aids, chronic disease, public health, nutrition, sport science and medical practice)	38	18.01%
Physical sciences (mathematics, chemistry, physics, nanotechnology, astrophysics)	31	14.69%
Environmental sciences (climate sciences, earth sciences, water, waste management, pollution)	16	7.58%
Engineering (energy, materials science, chemical engineering, infrastructure, electronics)	12	5.69%
Total	**211**	

In Table 4.1, I provide a breakdown of the broad fields of research represented by the 211 most visible scientists in South Africa. It is possible that the research opportunities presented in South Africa by the extraordinary biodiversity (Maze, Barnett, Botts, Stephens, Freedman & Guenther, 2016) and the unique fossil heritage in the country (Clarke, Partridge & Kuman, 2010) create opportunities for public science engagement, hence the presence of many biologists and palaeontologists amongst the visible scientists. Similarly, given the local health challenges (Shisana *et al*., 2014), it is understandable that HIV, tuberculosis and public health dominated as areas of expertise amongst the publicly visible health researchers.

The importance and relevance of social scientists in a developing country context was underlined by the fact that nearly a quarter of the publicly visible scientists (24%) were social science scholars working on topics such as politics, economics, gender studies, communication, criminology, violence, trauma and reconciliation. Notably, there were no social scientists or engineers in the group of the 18 most visible scientists. This meant that none of these scientists have achieved a similar level of visibility as the best-known experts in the country in fields such as palaeontology, climate change and HIV/Aids research.

The research fields of the 30 interviewees were split as follows: natural sciences (14), social sciences (7), health sciences (6) and physical sciences (3).

4.2.7. Visible scientists in South Africa per employment sector and institution

Of the 211 visible scientists, 160 (76%) were employed in the higher education sector, with 22 (10%) in science councils and 12 (6%) in the not-for-profit sector. There were relatively few visible scientists in industry (only 7, or 3%), and even fewer (only 5, or 2%) in government. Five of the visible scientists were retired and were no longer affiliated to a specific institution.

A breakdown of the institutions where the visible scientists worked (see Table 4.2) revealed that just more than half (109, or 52%) of the 211 visible scientists identified in this study were working at just four universities, while 74% (157 out of 211) were employed at just ten institutions. The rest of the visible scientists were thinly spread over 42 research organisations, with 27 of them featuring just one publicly visible scientist. Many universities, science councils and government departments are missing from the list of institutions hosting visible scientists.

The University of Cape Town proved to be home to most of the high-profile scientists in South Africa, followed by the University of the Witwatersrand, University of Pretoria and Stellenbosch University in the second, third and fourth places respectively.

Table 4.2: The top ten institutions in terms of publicly visible scientists in South Africa

Institution	Number of publicly visible scientists
University of Cape Town	37
University of the Witwatersrand	34
University of Pretoria	20
Stellenbosch University	17
Rhodes University	9
University of KwaZulu-Natal	9
University of Johannesburg	9
National Research Foundation (SKA & SAAO)	7
North-West University	7
University of the Free State	7

4.2.8. Leadership positions occupied by participating scientists

Of the 30 scientists interviewed, 28 were working in academic environments at the level of professor or assistant professor. In addition, 16 of them were appointed in leadership positions that further signified their leadership roles in the local science community (see Table 4.3). This meant that they enjoyed significant international recognition, and that they had extensive experience of international study, travel and collaboration. These scientists were therefore well placed to reflect on the science communication environment in South Africa compared to settings in other countries.

Table 4.3: Leadership positions occupied by participating scientists

Title and name	Leadership position
Professor Salim Abdool-Karim	Pro-vice-chancellor for research, University of KwaZulu-Natal
Professor Cathi Albertyn	Dean of postgraduate studies, Faculty of Commerce, Law and Management, at the University of the Witwatersrand
Professor Linda-Gail Bekker	Chief executive officer of the Desmond Tutu HIV Centre, University of Cape Town
Professor Lee Berger	Research professor in Human Evolution and the Public Understanding of Science, University of the Witwatersrand
Professor Don Cowan	Director of both the Genomics Research Institute and the Centre for Microbial Ecology and Genomics, University of Pretoria
Professor Pumla Gobodo-Madikizela	Research chair, Historical Trauma and Transformation, Stellenbosch University
Professor Amanda Gouws	South African Research Chair in Gender Politics, Stellenbosch University
Professor Glenda Gray	President of the South African Medical Research Council, with a dual appointment as professor at University of the Witwatersrand
Professor Sheryl Hendriks	Director of the Institute for Food, Nutrition and Well-being, University of Pretoria
Professor Bavesh Kana	Co-director of the DST-NRF Centre of Excellence for Biomedical TB (tuberculosis) Research, University of the Witwatersrand
Professor Tinyiko Maluleke	Advisor to the Vice Chancellor and Principal, University of Pretoria
Professor Tebello Nyokong	South African Research Chair Medicinal Chemistry and Nanotechnology, Rhodes University
Professor Linda Richter	Director of the DST-NRF Centre of Excellence in Human Development, University of the Witwatersrand
Professor Himla Soodyall	Director of the Human Genomic Diversity and Disease Research Unit, National Health Laboratory Service and University of the Witwatersrand
Professor Hamsa Venkatakrishnan	South African Research Chair in Numeracy, University of the Witwatersrand
Professor Cherryl Walker	South African Research Chair in Sociology of Land, Environment and Sustainable Development at Stellenbosch University

4.2.9. Participating scientists' status in terms of NRF evaluation and rating

I documented the status of interviewees in terms of the NRF evaluation and rating system, as another indicator of their academic status and research productivity. Scientists who apply for NRF evaluation and rating have to submit their recent academic track records and are then assigned a rating status (valid for five years) based on their scientific outputs and standing in the local and international science community. The process involves local and international peer reviewers.[56]

The broad rating categories are defined as follows.[57]

> **A:** Researchers who are unequivocally recognised by their peers as leading international scholars in their field for the high quality and impact of their recent research outputs.
>
> **B:** Researchers who enjoy considerable international recognition by their peers for the high quality and impact of their recent research outputs.
>
> **C:** Established researchers with a sustained recent record of productivity in the field who are recognised by their peers as having produced a body of quality work, the core of which has coherence and attests to ongoing engagement with the field, and demonstrates the ability to conceptualise problems and apply research methods to investigating them.
>
> **P:** Young researchers (normally < 35 years old) who have held the doctorate or equivalent qualification for less than five years and who – based on exceptional potential demonstrated in doctoral and early post-doctoral careers – are considered likely to become future international leaders in their fields.
>
> **Y:** Young researchers (40 years old or younger), who have held the doctorate or equivalent qualification for less than five years and who are recognised as having the potential to establish themselves as researchers within a five-year period after evaluation, based on their scholarly performance during their doctoral studies and/or early post-doctoral careers.

The 30 scientists interviewed for this study are listed in Table 4.4 according to their NRF rating status at the time of being interviewed. Of the 30 interviewees, 26 held an active NRF rating. Of these, 9 were A-rated, 11 were B-rated, 5 were C-rated and one was Y-rated, while 4 did not have a valid NRF-rating at the time of the interview.

[56] See www.nrf.ac.za/rating

[57] A detailed description of rating categories is available here [Accessed 6 May 2017]: http://www.nrf.ac.za/sites/default/files/documents/Rating%20Categories%202014.pdf

Table 4.4: Publicly visible scientists according to NRF rating category*

Visible scientist	NRF rating
Anusuya Chinsamy-Turan	A
Don Cowan	A
Jill Farrant	A
Glenda Gray	A
Tim Noakes	A
Tebello Nyokong	A
Linda Richter	A
Bruce Rubidge	A
Bob Scholes	A
Cathi Albertyn	B
Linda-Gail Bekker	B
Lee Berger	B
Kelly Chibale	B
Andrew Forbes	B
Pumla Gobodo-Madikizela	B (as from 1 January 2017)
Amanda Gouws	B
Bavesh Kana	B
Tinyiko Maluleke	B
Mary Scholes	B
Cherryl Walker	B
Marcus Byrne	C
Sheryl Hendriks	C
Nox Makunga	C
Francis Thackeray:	C
Hamsa Venkatakrishnan	C
Tolullah Oni	Y
Salim Abdool-Karim	Not rated
Dave Pepler	Not rated
Himla Soodyall	Not currently rated (rated as C and P before)
Anthony Turton	Not currently rated (B-rated before)

*As on 31 December 2016, unless otherwise indicated

4.3. Qualitative interviewing as a research method

The qualitative interview was well suited to the study, because of its relevance to understanding human thought, behaviour and meaning, with particular emphasis on the perspectives of selected individuals (Babbie & Mouton, 2001; Jensen & Laurie, 2016), as well as to detect nuances, personal preferences and emotions (Van der Auweraert, 2008). It is a useful approach to establish why specific people (or groups) respond in a particular way, as well as to understand the processes whereby their attitudes are formed (Palys, 2008). Furthermore, semi-structured, qualitative interviews, based on probing, open-ended questions, permit interviewees to reflect freely on their own knowledge and experience during a flexible conversation, which allows the interviewer to discover "what lies beneath the surface of a personal experience" (Jensen & Laurie, 2016:173).

In-depth interviews have been used by a number of science communication scholars as a research method to explore the public communication views and perceptions of academics in research environments. In the context of this study, notable examples are the interviews done with 15 Belgian scientists by Van der Auweraert (2008), the interviews by Rödder (2012) with 55 researchers connected to the human genome project, interviews by Horst (2013) with 20 leading scientists in Denmark, interviews with 133 physicists and biologists in elite academic environments in the United States as reported by Johnson *et al*. (2014), interviews conducted by Dijkstra *et al*. (2015) with 21 biomedical scientists in the Netherlands, as well as in-depth interviews conducted by McCann *et al*. (2015) with 12 university-based scientists in the United States, as well as 15 interviews conducted by Grand *et al*. (2016) with UK researchers.

4.4. The interview process and content

Targeted researchers were contacted via email[58] to request their permission to be interviewed, as well as to arrange the time, date and mode of interviewing. With the exception of one person who did not respond, all the scientists I contacted agreed to be interviewed. Only one scientist, who initially agreed, was eventually not interviewed due to his extended international travel commitments.

The interviews were conducted between January and March of 2017. Of the 30 interviews, 26 were done face to face (in an office or similar environment) and were recorded digitally. The other four were done (and recorded) via telephone, since cost and time constraints made it impractical to meet these scientists in person. The time duration of the audio recordings were between 55 and 90 minutes. The interviews were professionally transcribed, and the combined text of the 30 transcriptions added up to 310 760 words. This came to more than 700 pages of text at an average of 420 words per page. With the exception of one, all the interviews were conducted in English. The transcript of the Afrikaans-language interview was translated into English.

My in-depth interviews were based on the theoretical base and conceptual framework guiding the study (see Chapter 2). The aim of the interviews was to explore the views and opinions of publicly visible scientists in South Africa regarding their involvement in public science communication, but also to draw on their experiences of the barriers and constraints in public science engagement in order to arrive at policy recommendations.

During the course of the conversations, I encouraged interviewees to share their personal experiences and tell relevant stories. Moore and Ward (2008) emphasise the value of the stories told by scientists themselves to reflect on engaged scholarship in research environments. In terms of understanding the factors that motivate or constrain public communication, Qi *et al*. (2013:143) comment on the importance of determining the “real thoughts” of scientists about public

[58] Appendix 7 contains the text of the email sent to scientists to invite them to participate, which also included information about ethical research clearance, and the ‘declaration of consent’ form they had to sign prior to the interview.

communication in order to determine the underlying factors that motivate or constrain their participation and influence their behaviour.

Each interview started off with a discussion around consent, and each interviewee signed a consent form (Appendix 7) where they agreed to be identified and quoted in this study. Recognising that some of their answers could be considered as senstivie, I provided each interviewee with an opportunity to review the final text where he/she was quoted in this dissertation before it would enter the public domain (see 'member checking' in 4.5).

I explained to interviewees how they had been selected, based on the identification of visible scientists by the science-media panel. I furthermore made it clear to each interviewee that our conversation would be about the public communication of science, i.e. communication and engagement with audiences outside the academic setting. I then went on to question interviewees about three broad clusters of factors (background, attitudinal and contextual) to determine how these factors influenced their public science communication behaviour. I asked respondents about a range of questions related to their attitudes towards and experiences of engaging with external audiences. I used a trigger question for each of the factors, followed by probing questions if I needed more information. The interview framework is provided in Table 4.5.

Table 4.5: Outline of interview structure and questions

Cluster	**Factor**	**Questions**
Background factors	Research field	Does your field of research play a role in your involvement in public communication of science? What, in your view, about your research field or discipline makes it easy (or comparatively more difficult) to communicate to the public?
	Age and experience	In your view and experience, is public science communication easier or more difficult for younger (early career) compared to older (more senior) researchers? Do you think that there are reasons why young researchers should or should not be involved in public science communication?
	Gender	Do you think men and women in science experience different challenges and barriers, but possibly also different opportunities, in terms of being active in public communication about their work? Please explain.
	Population group	Do you see any differences in the public science communication challenges and opportunities faced by black and white scientists?
Attitudinal factors	Norms	In your view and experience, how does your participation in public communication of science affect your career? How do your colleagues and peers respond to your public visibility? Does this matter to you? Do their responses encourage or restrict your involvement in public science communication?
	Attitudes towards the public	In your view, how do public audiences view science? Are people generally interested in science? Who are the most important groups with whom you try to communicate? Which tools, tactics and platforms do you prefer to use to communicate your research to public audiences? Do you think the South African public should be involved in decision-making about science?
	Attitudes towards public	How do you see your own role in the public arena? What is the rationale for scientists to spend time and effort on public communication of science? Do you see a link between scientific reputation and public

Cluster	Factor	Questions
	science communi-cation	visibility? Is public science communication a central or peripheral activity in terms of your career? Where and how did your involvement in public communication of science start? What motivated you, and kept you motivated? What advice would you give to young researchers regarding public communication about their work?
	Attitudes towards mainstream media	How would you describe your relationship and interactions with the media? What are your main concerns about working with journalists?
	Attitudes towards social media	Please tell me what you think of using social media tools such as Facebook, Twitter, Instagram, blogs, etc. for communicating science to public audiences.
	Perceived moral duty	Do you think that publicly funded researchers have a moral duty to engage with the public about their research? In your opinion, should public engagement be demanded of all researchers?
	Self-efficacy	How easy or difficult is it for you to communicate about your work with lay audiences? What skills do you think are most needed for researchers to be successful at public science communication? Is it possible for scientists to become better communicators over time, and how? What is your view about training scientists in public science communication, including popular writing, media and social media skills?
	Personality	Are some scientists better suited to communicating with the public than others? What makes them good communicators?
	Perceived benefits and rewards	Have you experienced any particular benefits from communicating to the public about your work? What were the extrinsic rewards (tangible benefits) versus intrinsic (abstract) rewards?
	Perceived risks and fears	Are you concerned about any potentially negative consequences when you communicate to public audiences? What would you regard as the biggest potential (personal or career) risks associated with public communication of science? What, in your view, are the most important challenges or barriers facing scientists who want to become involved (or more visibly involved) in public communication about their work?
Contextual factors	National context	Which key aspects of the wider political and societal context in South Africa do you consider as important in terms of public science communication? Do you see any particular challenges or opportunities in terms of public communication of science in the South African context?
	Institutional environment	How would you describe the culture in terms of public science communication at the organisation where you work? Which support structures and/or incentives are in place to support public engagement at your institution? Do you think that it is necessary (or even important) to recognise and reward researchers who invest time and effort in public communication? Are public engagement efforts recognised and rewarded at your institution and in the science community in general? What kind of help or services would be most likely to encourage researchers' involvement in public engagement? Are there any institutional barriers that affect your involvement in public science communication? How would you describe your relationship with the communication and media staff at your university or the organisation where you work? What is their role in your public communication efforts? Which kind of support or services would you like to get from them?

Cluster	Factor	Questions
	Evaluation practices	How do you know that the money and time you spent on public science engagement was a good investment? Do you think it is necessary and/or possible to measure or evaluate researchers' public communication efforts? Have you ever evaluated your own science communication activities?
	Medialisa-tion	What are the expectations from your employer and/or funder(s) in terms of making your work publicly visible? (Are you experiencing increased demand, and even pressure, from your research organisation and/or funder(s) to make your work more visible via the mass media and social media?)

4.5. Data analysis and presentation

Qualitative content analysis has been defined as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh & Shannon, 2005:1278). Coding is an integral part of processing interview data (Hsieh & Shannon, 2005; DeCuir-Gunby, Marshall & McCulloch, 2011). By assigning a code (or tag) to units of text (phrases, sentences or paragraphs), the process of coding helps to rearrange large volumes of interview data into meaningful categories, make connections between concepts, and extract new meaning and ideas that help to interpret the data (Forman & Damschroder, 2008). It furthermore allows the researcher to examine how the data support or contradict the theory that guides a research project (DeCuir-Gunby *et al.*, 2011).

In this study, the interview texts were coded deductively, informed by the conceptual framework and literature review that guided the study (Mayring, 2000). In other words, I used a set of fixed codes based on the theory and conceptual framework guiding this study and focused on data relevant to my research question. My coding frame consisted of a unique code to each of the factors (18 in total) listed in Table 4.5. This comprehensive set of codes proved to be sufficient to code the interview data, i.e. it was not necessary to add new codes inductively.

During the coding process, I read the 30 interview transcripts line by line, reading and coding one full transcript after another. If there was any reason for uncertainty about any aspect of the transcript, for example where the transcriber indicated that she could not decipher a specific word or phrase, I listened to the relevant section of the audio recording and updated the transcript as necessary. Similar to the approach followed by Casini and Nerisini (2012), I selected interview data relevant to my research question. In other words, some of the interviewees' responses that were not relevant were not coded. I used ATLAS.ti software to support the text-coding process.

In Chapter 5, I present my findings according to the conceptual framework of the study, i.e. I present data on background, attitudinal and contextual factors sequentially. Given that this was a qualitative study (and that I interviewed only 30 scientists), my analysis focused on the content of their responses, illustrated by relevant direct quotes. I have incorporated some discussion into the presentation of the findings. This is one of the options for reporting on qualitative research suggested by Burnard, Gill, Stewart, Treasure and Chadwick (2008). In a few cases, I presented some quantitative data in order to indicate the weight of opinion within my sample of visible scientists. Since I interviewed only 30 individuals, my goal was not to provide any statistical analyses, but simply to indicate the majority view where relevant.

Given that interviewees are identified in this thesis (i.e. statements were **not** anonymised), I provided each interviewee with an opportunity to review their statements for descriptive and interpretive validity, a process known as 'member checking' or 'respondent validation' (Sandelowski, 2008). Member checking is considered a useful step to optimise the reliability of interview data (Creswell & Miller, 2000). It was therefore regarded as important to ask interviewees to verify my interpretation of their views, while making sure that I would not lose any data (Thomas, 2017). Instead of expecting interviewees to read the full interview transcripts, I provided them with relevant extracts (Creswell, 2014) and provided instructions in order to avoid some of the common challenges associated with member checking (Carlson, 2010).

In the reporting of the findings, I refer to the 30 scientists that I interviewed simply as 'participating scientists' or 'interviewees'.

Chapter 5: Results and discussion

In Chapter 5, I present and discuss key findings from the current study, supported by selected extracts from the interview data resulting from my interviews with 30 scientists[59].

5.1. Background factors

Background factors (i.e. research field, age, gender and population group) comprised the first cluster of factors that were explored.

5.1.1. The influence of research field

If public health researchers are not engaging with the public, then what is the point of their research? *(Tolullah Oni)*

HIV is in the public eye and HIV rumours spread rapidly, because so many people are desperate. So, we need a lot more communication about HIV than about any other disease. *(Salim Abdool-Karim)*

The current study did not compare the frequency of visible scientists' involvement in public communication across different fields of research, but it did solicit their opinions about how their field of research influences their views of and involvement in public science engagement. Please note that all quotations are reproduced verbatim and unedited.

"Digging up fossils is glamorous?" Lee Berger asked smilingly when we discussed what made his field of research so popular with the public. "Fossil hunting is only popular because we have managed to make it adventurous and exciting. Otherwise, they are little more than rocks."

In my interviews with visible scientists, I asked them whether they thought that their particular field of research made a significant difference in terms of their ability to connect with broad society, as well as whether certain topics in science were easier or harder to communicate than other topics. They overwhelmingly agreed (22 out of 30) that the field of research made a difference when it came to communicating their research. They perceived that people were simply fascinated by some topics, such as the night skies and the unique fossil heritage in South Africa. Similarly, they saw a particular public interest in fields that were close to everyday concerns, such as health, food and the environment. By contrast, more esoteric and abstract research fields were generally perceived to be particularly challenging in terms of attracting public interest. Frequently, visible scientists described themselves as 'lucky' to be in a field that had public appeal, and the personal or societal resonance of their work was perceived as a key reason why people were interested.

> **Jill Farrant**: What I am doing is tangible. People understand it. And, when I show a video of a resurrection plant, people find it amazing.

[59] In the presentation and discussion of the interview data, I refer to the scientists I interviewed as 'interviewees', 'visible scientists', 'participating scientists' or 'scientists in the current study'.

> **Himla Soodyall**: People find genetic ancestry testing appealing. It is close to home. It strikes a chord.

> **Marcus Byrne**: My public work is on dung beetles. People know them, so that makes it easy. And, believe or not, they identify with these little, hard-working insects.

> **Pumla Gobodo-Madikizela**: People are able to relate to research topics that have to do with human experiences, such as trauma, which is my field. People feel, 'Oh that is exactly what happened to me'.

When reflecting on the public appeal of their own research, visible scientists contrasted their fields with others that they perceived to be much harder to communicate.

> **Amanda Gouws**: Are people interested in mechanical engineering? I doubt it. But, if you talk about political analyses based on research – that is a different matter.

> **Bob Scholes**: When I speak about the environment, I can make connections to anybody – from white, urban people to poor, rural dwellers. We can find some common ground, because it is a shared environment. It would be much harder for a particle physicist. People know what a tree is. They know what a bird is. People don't know what a Higgs Boson is.

> **Tinyiko Maluleke**: Theology is, by nature, connected to the public. It is not an esoteric field which sends you to the lab to spend hours in isolation.

The majority view of visible researchers in South Africa was that the public was more interested in topics close to everyday life that resonated with human interest. In this, they agreed with scholarly opinions and findings from Goodell (1975), Mathews *et al*. (2005), Jensen *et al*. (2008) and Peters *et al*. (2012). In line with the perception of 22 out of 30 visible scientists in the current study, these authors found that it is easier to make topics close to people's daily lives, especially social science topics, relevant and interesting to public audiences, while it is comparatively more difficult to communicate jargon-rich, highly codified and abstract fields, such as mathematics and physics (Bentley & Kyvik, 2011). The proximity of the natural and health sciences to people's everyday lives, as well as the ethical and moral issues raised by these fields of research, has been suggested as a further explanation why researchers working in life and health sciences are more involved in public engagement (The Royal Society, 2006; Burchell *et al*., 2009).

One of the interviewees, Andrew Forbes, challenged the widely held view that physics is a remote and hard-to-communicate field, as was argued by Morus (2009). "Physics tells us how the universe works," Forbes said, "and it catches the imagination." He acknowledged, though, that it could be hard to make cutting-edge physics palatable for a lay audience and admitted that, when he engaged public audiences, he focused on the broader picture of physics, rather than his own high-level research. He made an interesting case for the public visibility of physicists.

> **Andrew Forbes**: If you ask any person on the street to name a few famous scientists, I will bet that all the names that they will give you will be physicists. They may think of Einstein, Newton or Galileo. They will not name a palaeontologist, or a chemist or climate change researcher. I will bet my life on that. So, physics can be difficult, that's true, but it tells us how the universe works, and people enjoy that.

Interestingly, Forbes also plays on 'everyday connections' when he promotes his public appearances. During 2015, he presented a series of talks around South Africa in support of the UNESCO International Year of Light and Light-based Technologies. His talks focused on how the story of light went beyond science, and touched on art, culture and life.

Science communication scholars agree that scientists working in abstract fields, such as theoretical physics, can and do become highly visible. For example, Fahy (2015) features three physicists who managed to make hard topics palatable to the public in *The new celebrity scientists*, namely Stephen Hawking (black holes), Brian Green (string theory) and Neil DeGrasse Tyson (astrophysics). The palaeontologists I interviewed perceived a particularly strong public fascination with their field, which they ascribed, at least partially, to the rich fossil heritage in South Africa.

> **Bruce Rubidge**: People are interested in dinosaurs, so we have a lot of public interest to latch onto. And, we have brilliant fossils from the Karoo. They come from here and you can see them and touch them. People find that exciting.

> **Francis Thackeray**: In South Africa, astronomy and palaeontology have created celebrities.

Interviewees pointed out that, within broad fields of research, some narrow areas were perceived to be much more popular with the media and/or public than other areas.

> **Cathi Albertyn**: Even within law, some areas are more in demand. Criminal law is big. Everyone wants to talk to a criminal lawyer.

> **Mary Scholes**: When I worked more narrowly as a plant physiologist, I never had anyone phoning me saying: 'Won't you please tell us how the nitrogen cycle is intertwined with amino acid syntheses'. It was amazing work on food security, but I never spoke to a single journalist about that.

Some visible scientists felt quite strongly that all fields of science could be communicated to public audiences, including abstract fields such as mathematics.

> **Dave Pepler**: If you have a heart and a mind for your subject, you can make it exciting. I don't care what you're working on – it can be rats' arses, but if that is your chosen research topic, you can find a way to get people interested.

> **Lee Berger**: I don't believe there is an area of science that could not attain huge levels of popularity if communicated well.

> **Tebello Nyokong**: Even mathematics can be related to reality, if you think hard enough. Any scientific topic can be presented in a way people can understand.

Interviewees pointed out that public interest in science depended, at least to some extent, on the effort and expertise on the part of the scientists who were doing the communication. They acknowledged, though, that it requires much effort to make some topics publicly appealing.

> **Linda-Gail Bekker**: Physicists can make their subject interesting. Similarly, you can make what I do, incredibly dry and boring. It is up to the individual scientist.

> **Anusuya Chinsamy-Turan**: We recently did a popular article about mole rats. It was difficult. It was not as if we were talking about polar bears that everyone cares about. But, somehow, I believe, you can find a way to make people care.

In some cases, interviewees were concerned that they were known for a specific topic, and were rarely asked about anything else. They also expressed concern about the perceived popularity of some fields over others. Furthermore, they acknowledged that public (especially media) interest in topics changed over time, influenced by politics and other trends in society.

> **Cathi Albertyn**: Because I started off in women's rights, I am now seen as the women's rights expert. As soon as you are seen to be willing to talk about your race or your gender, then that becomes all people want you to talk about.

> **Marcus Byrne**: I've been labelled in the public sphere as 'the dung beetle man', but, my bread-and-butter research is really about the biological control of alien weeds. I do wonder if I lose credibility with some of my colleagues for always talking about dung beetles in public. It is a double-edged sword. You have some sort of notoriety, but it also makes you a one-dimensional individual.

> **Nox Makunga**: Certain topics in science are sexier than others and become popular at the expense of others. It is a problem when we actually need more young scientists in less popular fields.

> **Cherryl Walker**: I have been working on land issues for a long time, but suddenly it is in the public and political domain in a way that makes it topical. Now, I get lots of queries and people wanting to talk to me. It is quite fickle. It does come and go.

5.1.2. Research field: summary

Scientists who worked on research topics that resonate with everyday life, found it easier to engage public audiences and have more opportunities to do so. They used words like "tangible", "close to home", and "relate" to explain why their research was easier to communicate. But, while communicating 'hard' topics required more effort, there was ample evidence that it was possible to engage lay audiences in esoteric and abstract science topics, suggesting that the way a specific topic is communicated may be more important than the topic itself.

Furthermore, the split between topics that do or do not resonate with public interest was not simply a matter of research field. Within narrow disciplines, some topics had more media appeal than others, while events in society and politics increased the focus on a specific topic for a period of time. These findings are in line with Goodell's (1975) observation that the visibility of scientists rises and wanes as topics move in and out of vogue.

5.1.3. The influence of research productivity

I believe that those who are really good at what they do, realise that it is important to share it beyond the narrow field.
(Tinyiko Maluleke)

While the current study did not analyse the research productivity of publicly visible researchers, there were other indicators that the interviewees were leading and productive researchers.

The respondents in this study were identified by a panel consisting of journalists and others working at the science–media interface. Being identified by this panel was already a strong indication that these scientists were scientifically productive, as journalists prefer to contact highly productive scientists (Dunwoody *et al*., 2009). Moreover, scientists who are actively involved in public communication (and therefore more likely to be identified as visible) typically have a higher academic status, including more scholarly publications (Jensen *et al*., 2008; Dudo, 2013) than other scientists.

I applied three further indicators of academic status to verify the research productivity of the respondents in this study, namely professional titles, institutional appointments and rating status at the National Research Foundation (NRF).

Of the 30 scientists interviewed for this study, 26 were appointed as professors, and two as assistant professors at the time of my interviews with them. This indicated that the bulk of the interviewees were research-active.

Furthermore, more than half of the interviewees occupied leadership positions in their research institutions, over and above their appointments as researchers and/or lecturers (see Table 4.2). This confirmed their status as leading (and therefore productive) scientists.

Obtaining and sustaining a valid A, B, C or Y rating from the NRF in South Africa requires a considerable and sustained level of academic output (see the description of rating categories in section 4.2). As such, the NRF rating system can be used as another indicator of research productivity. The fact that 26 of the 30 interviewees (86%) held a valid rating at the time of the interview (see Table 4.3) meant that they were judged by their peers to be academically productive, confirming a high degree of correlation between academic productivity and public visibility. (Note: not all scientists in South Africa subscribe to the NRF evaluation and rating system. Therefore, the absence of an NRF rating does not mean that a scientists not academically productive.)

While I did not ask respondents about their academic outputs, several remarks illustrated that they regarded academic output as vitally important and that they saw a link between academic output and credible public communication of their work.

> **Tinyiko Maluleke**: If you are able to demonstrate academic excellence and a commitment to public engagement over many years, you achieve what I call 'complete impact' – impact among your peers, but also impact in society. The best scientists over time have had both.

Linda-Gail Bekker: I have about 300 scientific publications and publish about 30 papers per year. I do my share of the peer-reviewed publications. If you're not publishing for your peers, your credibility will be questioned.

5.1.4. Research productivity: summary

The bulk of publicly visible scientists in South Africa was also academically productive and enjoyed a high status in the local academic community. This was evident from the level of their professional appointments (28 of the 30 were professors or assistant professors at the time of this research) and the leadership positions that they occupied (more than half of the group were appointed in leadership positions within their institutions). This confirmed earlier research findings that research excellence and knowledge production are clearly linked to public dissemination activities, with high-performing researchers significantly more involved than their less productive peers (Jensen *et al.*, 2011; Wigren-Kristoferson et al., 2011); as well as that publicly visible scientists are typically also leaders in the science community (Fahy & Lewenstein, 2014) and that, in many respects, they represent the scientific elite (Bucchi, 2015).

5.1.5. The influence of age and experience

Young researchers often give a take on things that are breathtakingly innovative. *(Bob Scholes)*

Age makes the difference between knowledge and wisdom. *(Dave Pepler)*

In an academic environment, age usually goes hand in hand with experience and seniority. Consequently, this discussion is (mostly) restricted to a discussion of age. All the visible scientists I interviewed were of the opinion that scientists could, and should, communicate with external audiences over the duration of their academic careers. They noted that other factors (such as communication skills) mattered more than age when it came to effective public engagement.

Nox Makunga: It is not age that counts – it is about how well you communicate.

Glenda Gray: There is room for researchers of all ages to communicate.

Anusuya Chinsamy-Turan: There is no need for scientists to wait until they are older before communicating with the public.

Andrew Forbes: The earlier you start, the better.

Visible scientists' belief that young scientists should communicate was linked to the idea that young researchers have a right to communicate their own work, and that they were entitled to academic autonomy.

Francis Thackeray: If you have discovered something important and you have a story to tell, it does not matter whether you are 26 or 62. It is your story; you should tell it.

Tim Noakes: It is your career. You decide when to communicate.

In particular, visible scientists did not agree with the idea that scientists should wait until they reach a certain level of appointment or status in the academic world, before stepping out into public life.

> **Tebello Nyokong**: I completely object to the idea that you need a title to be regarded as an expert.
>
> **Cherryl Walker**: I definitely do not agree that only professors are worthy of listening to.

However, visible scientists acknowledged that academic credentials offered a reputational advantage in the public sphere.

> **Bob Scholes**: It does help having positional power – being introduced as professor or doctor – these credentials certainly help, but it should not be an impediment for young researchers that keep them from communicating about their work.
>
> **Pumla Gobodo-Madikizela**: Position is important, and professors are taken more seriously.

Interviewees perceived that older scientists were generally more confident when it came to public communication, compared to their younger colleagues. These perceptions were in line with findings from several earlier studies (MORI, 2001; Bond & Paterson, 2005; The Royal Society, 2006; Jensen *et al*., 2008; Mizumachi *et al*., 2011; TNS-BMRB, 2015).

Participating scientists suggested a number of reasons why it was important for researchers to start communicating early in their careers, including how starting with public engagement at an early stage themselves, benefited their own careers. They were aware that a discouraging attitude towards young researchers could affect their future attitudes to public engagement.

> **Glenda Gray**: How will young researchers gain experience with the media, unless they start doing it early on?
>
> **Bavesh Kana**: You need to start communicating with the public when you are young. You cannot suddenly turn it on later in your career.
>
> **Tolullah Oni**: Communication with the public has got to start early, otherwise you are trying to teach an old dog new tricks! Getting older does not come with a side order of communication skills.
>
> **Bavesh Kana**: I was given communication opportunities when I was young. That is why I can communicate now.
>
> **Lee Berger**: There is no stage of your career when you should not communicate. Perhaps those who believe that, were disadvantaged by their seniors who prevented them from communicating.

The shared view that hands-on involvement is an effective way to acquire communication skills and develop confidence, is similarly evident from earlier research (Pearson *et al*., 1997; Blok *et al*., 2008; TNS-BMRB, 2015).

In addition to the career benefits of starting with public engagement early in an academic career, interviewees noted that young scientists have several advantages over their older colleagues when it comes to engaging the public. Views from other scholars and findings from earlier studies agree that young scientists (or graduate students) are best placed to connect with young audiences as well as to recruit future scientists (Beck, Morgan, Strand & Woolsey, 2006; Quimby, Seyala & Wolfson, 2007; Messinger, Schuette, Hodder & Shanks, 2009).

> **Anusuya Chinsamy-Turan**: Postgraduates work on novel topics and have interesting new information to present.
>
> **Bavesh Kana**: Young scientists make better role models and connect better with young audiences.
>
> **Linda Richter**: Young scientists make their work come alive. Older scientists are often boring.
>
> **Cherryl Walker**: Young people have new ideas and new perspectives.
>
> **Tebello Nyokong**: Some of these young scientists are more confident than you or me. They don't even mind going on television!

In contrast to Nyokong's comment about the confidence of young researchers in front of television cameras, earlier studies show that scientists become more confident about interacting with the media over time (Gascoigne & Metcalfe, 1997; Metcalfe & Gascoigne, 2009).

While they would encourage young scientists to engage with external audiences, visible scientists felt that these young scientists should take extra precautions when they step out into public life, and that they have to be particularly mindful of the risks. Earlier studies confirm that inexperience may lead to anxiety and apprehension amongst young scientists when it comes to taking part in public science events (Bond & Paterson, 2005; Mizumachi *et al*., 2011). In line with this, some visible scientists suggested that early-career scientists should make sure that they are well prepared before stepping out into the public view, and that they should possibly focus on easy content and youthful audiences.

> **Kelly Chibale**: Scientists should not wait until they are older before communicating with the public, but young scientists need to be aware of the risks. The danger of giving out wrong information is much higher when you're young, simply due to lack of experience.
>
> **Salim Abdool-Karim**: As long as young scientists know their subject matter well and have the confidence to do it, they should communicate. But, it may not be easy for them.
>
> **Andrew Forbes**: Young scientists should leave complex topics and issues to the experts. It is better for young scientists to start their engagement work at schools. That is a good place for PhD students to learn outreach skills.

Visible scientists were aware of the changing science communication landscape and that social media, in particular, were opening up new communication opportunities ideally suited to younger researchers.

> **Cathi Albertyn**: Young people have social media dexterity, right? They are much more comfortable with these new tools.

> **Sheryl Hendriks**: It is different in today's age. When I was young, it was very difficult to talk to a journalist if you did not have a title. Social media has changed that entirely. And, the young scientists are much better at it than we are.

Despite the broad agreement that young scientists could and should engage with external audiences, visible scientist noted that, at least in some ways, public science communication becomes easier and less intimidating with age and experience.

> **Mary Scholes**: Now that I'm older, it is much easier to talk to journalists.
>
> **Cathi Albertyn**: As you get older, you become more confident – without question. And I care less now what people think of me than I did in my twenties or early thirties.
>
> **Amanda Gouws**: The ability to read situations and audiences comes with time. You also become more at ease about controversial topics.
>
> **Bavesh Kana**: I became much less nervous about public speaking as I got older.
>
> **Bruce Rubidge**: The experience that comes with being older helps you to anticipate questions, while young scientists may be rattled by unexpected questions.

Visible scientists were aware of (and sympathetic towards) the challenges that young scientists face when they try to communicate in public.

> **Himla Soodyall**: It is hard for young scientists to get recognised as experts. Journalists tend to go to people with an established reputation. Younger people are often side-tracked.
>
> **Bruce Rubidge**: Young people, because they lack experience, often make mistakes. They are entitled to make mistakes.

Based on their own experience and belief that scientists should participate in public communication from the outset of their careers, interviewees made an effort to encourage and support their young colleagues towards raising their public profile.

> **Himla Soodyall**: We must create communication opportunities for young scientists. When a film crew comes here, I try to get my younger colleagues in front of the cameras. We should not keep these opportunities to ourselves.
>
> **Tebello Nyokong**: The media always want to come here and talk to me. I say: 'No, talk to my students'. They do the work in the lab, they know what they are talking about, and young people can relate to them.

Visible scientists were acutely aware that skills in public communication were honed over time and through hands-on involvement.

> **Bruce Rubidge**: I encourage my students to engage with the public and media in whatever other way they can. I encourage them to tell their research stories. They have to take around the school groups. They learn by doing it.
>
> **Jill Farrant**: It was through doing public talks that I learned at what level to pitch my science for different audiences. It is a huge learning curve.

5.1.6. Age and experience: summary

Some scientists can, and do, become publicly visible relatively early in their careers. Those who have achieved public visibility were uniformly in favour of involving researchers in public communication from the outset of their academic careers. Participating visible scientists were convinced that researchers should start with public communication early in their careers, even as soon as they possibly could.

Visible scientists based their support for the communication activity of early-career scientists on the principle that young scientists have a right to communicate their own findings, but also that they have some advantages over their seniors when it comes to connecting with the youth and using social media. Consequently, visible scientists went out of their way to create engagement opportunities for their students and younger colleagues. However, interviewees were aware of the risks of going public and agreed that they advise younger colleagues to make sure of the integrity and accuracy of the information they share in public. They acknowledged that young scientists could make mistakes along the way, but they showed lenience in this regard.

5.1.7. The influence of gender

> ***Some of us face a double jeopardy in science – being black and being female.*** *(Pumla Gobodo-Madikizela)*

In this section, I reflect interviewees' responses related to whether being male or female made a difference when it came to public science communication. More than half of the 30 visible scientists interviewed (n = 18) felt that women faced different and more stringent barriers and critical responses when they communicated in public. Seven interviewees saw a difference between men and women in this regard, but felt that the situation was improving. The minority (n = 5) felt that there was no difference in peer or public responses to women who become publicly visible, and that men and women faced the same barriers and constraints in terms of public science engagement. Furthermore, most of the visible scientists perceived persistent gender stereotypes about science in our society.

> **Andrew Forbes**: If you ask a young girl who study science to draw a scientist, she will draw a man. And, if you ask a hundred, 98 will draw a man. That is terrible. We have to fix that.

Visible scientists who saw a difference in the way male and female scientists were treated in public life, offered a range of reasons that were frequently linked to the patriarchal nature of South African society.

> **Tinyiko Maluleke**: It shouldn't matter whether one is a woman or a man, but – as with everything in our patriarchal society – it does matter. We would be fooling ourselves if we denied that. Women have a hard time wherever they go. It would be a miracle if in the field of science engagement with society this was not a problem.

> **Anusuya Chinsamy-Turan**: In our society, men still have it much easier than women. Lots of young men in South Africa continue to grow up with the stereotype that women should be at home raising children. That is part of a much bigger problem in our society. Women who

make it to university to study science, may even face a situation where their immediate family looks down on them.

Jill Farrant: There is still a lot of prejudice against female scientists; not necessarily evil intent, just ingrained prejudice.

Bavesh Kana: It would be naïve to say that men and women in science are treated the same way – they are not. Women are on the receiving end of very harsh judgements. Also, depending on how they were brought up, it can be extremely difficult for young women to draw attention to themselves.

In line with the comments above, societal expectations around the role of women in family life were perceived to be a major factor when it came to public visibility. In particular, having children (or not) was perceived as an important determinant in women's ability to participate in the public science arena.

Cathi Albertyn: I withdrew from the public eye when I had children – it was just too much. When my children were young, something had to give, and I was less willing to spend half a day reading up and thinking about a long radio interview that evening.

Himla Soodyall: In our society, women are seen as mothers and they have extra responsibilities. That is why many women get to a certain career level and don't pursue going further. I am single and I have no children, so these issues did not affect me.

Anusuya Chinsamy-Turan: It is possible to be a scientist, a mother and a public communicator, but this balancing act is not always easy and it is a huge issue for young women entering careers in science. It will help them if we speak more openly about how women cope with multiple demands in their lives. That is why it is important to me to share my experiences and offer some guidance.

Thackeray used the example of Chinsamy-Turan to illustrate that highly visible women in science could simultaneously have an excellent academic career. Interestingly, Chinsamy-Turan, herself, saw a persistent gender bias in science in South African society, but she agreed with Thackeray that this bias did not extend to the public engagement sphere.

Francis Thackeray: I don't think gender matters at all. Look, for example, at someone like Anusuya Chinsamy-Turan and her work on dinosaurs. She is doing exceptionally well in her science career, while working hard on promoting her field in public.

Anusuya Chinsamy-Turan: The playing fields for men and women are not the same in science. Women have a lot more stacked up against them. But, I don't think that men and women in science are treated differently when they become publicly visible.

Scholes did not perceive gender differences, but admitted that this could simply be because he was a man.

Bob Scholes: I think the similarities in the way men and women in science are treated are more than the differences, but until you have stood in someone's shoes, you can't say the gender differences are imagined or irrelevant.

Richter referred to Gray, a woman in a high-profile position, to make her case. Gray agreed that women in science faced credibility challenges.

> **Linda Richter**: Yes, men and women get different responses – also from other scientists. I've heard scientists make remarks about Glenda Gray, the president of the Medical Research Council, saying that she is a beautiful, attractive woman. I think she is not taken as seriously as a man would have been in that position.

> **Glenda Gray**: Women – here and around the globe – still face immense challenges in terms of being seen as credible scientists, particularly women of colour.

In line with Richter's comment, both male and female interviewees felt that one of the prejudices women faced when going public, was that they were judged on their appearance.

> **Amanda Gouws**: When a woman scientist walks into a room, the initial judgment is on how she looks, and then on who she is and what she says.

> **Anusuya Chinsamy-Turan**: People still judge women for how they look. Men are not judged on their appearance.

> **Linda Richter**: For a woman, it still depends on how you look. Women seem to have more authority when they wear lab coats and thick glasses.

These comments about women scientists being judged on appearance, and women feeling that they had to downplay their femininity in order to be taken seriously in a science environment, were in line with findings that women with a feminine appearance are deemed less likely to be scientists, and that a feminine appearance has the potential to have a negative effect on their career trajectories (Banchefsky, Westfall, Park & Judd, 2016). Similarly, Chimba and Kitzinger (2010:621–622) show that mass media features about women in science tend to focus on their appearance, adding that women are judged on "beauty, fashion and sexiness", whereas "men appear to convey an aura of gravitas". The authors conclude that male scientists are still the norm and that, consequently, media coverage of female scientists focuses on their exceptional status as 'women in science'. By contrast, in terms of the perception that women must dress a certain way to appear authoritative, Byrne perceived that he automatically enjoyed authority in public conversations.

> **Marcus Byrne**: It is completely true that men and women in science are treated differently in public domains. Being a grey-haired, white male, people will turn to me as a figure of authority. They shouldn't, but they do.

Additionally, Byrne noted that the nature of attention women attracted in the public sphere might not be what they were hoping for in terms of engaging people in their research.

> **Marcus Byrne**: When women are speaking in public, their femininity is judged as much as their knowledge. Just look at the hits on TED talks – the good-looking women score many more hits than the ordinary-looking men and women. And I guarantee people are not watching that for the science, or the entertainment or the education; they are watching but because it is a woman. So you could say: Oh, it is great, because you are getting attention as a woman. But you are not getting attention for the right reasons.

Some scientists felt that female scientists could use the fact that audiences responded to them differently, to their advantage, and that being female could offer some advantages when communicating science in public.

> **Jill Farrant**: A man has more authority standing up on a stage than I do. But, as a woman, I can make a different connection with the audience. I meet people's eyes and actually talk to them. I make them feel needed and wanted. I get their empathy.

> **Bavesh Kana**: When a woman is talking to a group of young people that are mostly guys, they may undermine her by making comments and whistling. It is hard, because she is there for her intellect. But, at least she has their attention, right? So, rather than be offended, perhaps she could use that.

> **Lee Berger**: The women in our expeditions – often working under dangerous conditions – added an immense quality and created unique communication outputs that I believe would not have been possible with all-male teams.

Some of the visible scientists noticed a change in society over time, making it more acceptable for female scientists to become publicly visible, and observed that some women were doing exceptionally well on this terrain.

> **Mary Scholes**: Gender bias against women is still real, but it is nowhere near as strong as it was 20 years ago. There are now many extremely well-spoken female scientists in South Africa. They have made it much easier for the next generation.

> **Linda-Gail Bekker**: There is definitely still an element of gender bias when female scientists are judged for their public engagement work, but it is getting better.

> **Dave Pepler**: There is a new breed of women in science today who are extremely confident and powerful. You would not dare tell them they are inferior scientists because they are publicly visible.

While Albertyn felt that the gender argument was losing ground, she admitted that it could still take a specific effort on the part of female (and black) scientists to gain public recognition.

> **Cathi Albertyn**: The gender argument is that people expect men to be in the public eye – they are regarded as more equipped, more intelligent, better read. Men have more time to publish, because they are not at home looking after children. When you think about success, you think about men. I think it is becoming less true. But, for women (and black scientists) to be recognised equally, they need to put themselves out there.

Visible scientists who saw no difference between men and women in public communication often based their views on the perception that, in science, it was quality that counted, and nothing else.

> **Kelly Chibale**: The bottom line is, if you're good, you're good. It does not matter whether you are a male or female scientist.

> **Don Cowan**: When I look at top women scientists around me, they have the same level of recognition and visibility as the top male scientists.

In some cases, interviewees pointed out that the nature of a specific target audience made it difficult for women to be in the front-line of engagement. For example, Rubidge believed that gender should not determine what scientists do in public life, but he admitted that, occasionally, women faced additional barriers when it came to engaging audiences, such as rural farmers.

> **Bruce Rubidge**: Sometimes farmers do not take female students seriously when they request permission to do fieldwork on their farms.

Women also saw particular gender biases linked to their own research field.

> **Amanda Gouws**: When I started at *Beeld*[60] as a young journalist, with postgraduate qualifications in journalism and political science, they absolutely refused to let me do the political beat. I had to do fashion and children and things like that. I lasted six months. I have had to cope with that expectation – that politics are a playing field for men – during my entire career.

Female scientists were conscious of the need for female role models in science and would encourage female colleagues to help combat gender stereotypes.

> **Nox Makunga**: Role modelling of black women in science is vital, because we are rarely seen or heard. Young South Africans don't understand what scientists do – it is still a mystery to many.

> **Hamsa Venkatakrishnan**: Young women scientists need to get comfortable about public appearances, but should be aware of gender stereotypes so that they can help to combat them.

Female scientists recognised the reputational power of having women in science leadership positions, and they made an effort to support their female staff towards public engagement.

> **Linda-Gail Bekker**: When the president of the Medical Research Council is a woman, and the president of the International Aids Society is also a woman – that helps.

> **Glenda Gray**: I strategically choose women on my team to show that I'm committed to empowering women in science. I try to put young women in a position where they can shatter gender stereotypes and inspire others. I include young black and Muslim women – to show the community that they can be scientists too.

Gender stereotypes inspired some visible scientists to prove people wrong, particularly those who continue to cling to gender stereotypes.

> **Nox Makunga**: When I walk into a venue as a speaker, people may think, what does this short, black woman know? It is up to me to shift that prejudice.

> **Tebello Nyokong**: Gender stereotypes are always there. The way to empower ourselves is by being the best, standing our ground, and rising to the top.

[60] *Beeld* is a daily newspaper in Gauteng, a province of South Africa.

In line with these findings, there is widespread agreement that one of the ways to correct the gender imbalance in science would be to make female scientists more visible via public profiling (Harvey-Smith, 2017) and that Africa, in particular, needs more female role models in science (Asimeng-Boahene, 2006).

5.1.8. Gender: summary

Visible scientists in the current study overwhelmingly agreed that women continued to face different barriers and more constraints than men in terms of public communication about their work, and that this could shape their involvement in public engagement. These gender barriers were perceived to be particularly prevalent in South African society, given the patriarchal nature of many communities, and the dominance of men in research environments.

5.1.9. The influence of population group

Science is not necessarily given the face of a black woman. People think of science as something that is done by old, white men.
(Nox Makunga)

I report here on how visible scientists in the current study responded to the link between a scientist's population group and her/his public science communication behaviour. More than two thirds of the 30 interviewees (n = 21) felt that black and white scientists faced different barriers and experienced divergent responses when communicating in public. A range of advantages and disadvantages in terms of communication efficacy were associated with the ethnicity (and associated language abilities) of the communicating scientist. Three scientists noted that racial prejudices of the past were still present in society and therefore had an effect on scientists who appeared in public, but pointed out that this situation was steadily improving. Six interviewees saw no difference between black and white scientists as far as public communication was concerned.

As is the case with gender, visible scientists perceived that it was important for young people to engage with scientists with whom they could identify. "It is incredibly necessary for young people to see scientists that they can relate to," Bavesh Kana noted, while Anusuya Chinsamy-Turan said, "It is incredibly important for township children to meet successful black scientists." Consequently, in a country like South Africa where the vast majority of the population is black,[61] visible role modelling of black scientists is regarded as an important aspect of public science engagement.

Participating scientists who saw a difference in the audience responses when black and white scientists communicated, frequently emphasised that this did not necessarily mean one is better than the other. Instead, it simply means that, depending on the audience and the situation, it would be better if the communicating scientist represented a particular ethnic group. They linked this to

[61] According to most recent population estimates (Statistics South Africa [Stats SA], 2016) the total South African population stands at 55.9 million people, of whom 92% are black (80.7% African, 8.8% Coloured and 2.5% Indian) with whites comprising 8.1% of the total population.

the perception that audiences responded more enthusiastically to someone from the same population group. Kana talked about his own experience of engaging learners at his former school:

> **Bavesh Kana**: When I go back to my school – a predominantly Indian school – the learners see an Indian guy standing up there who looks just like them and who has been through the same process as them – and they can see a future for themselves.
>
> **Anusuya Chinsamy-Turan**: Now that we have more black scientists, they must become visible in their own communities, and reach out to children who hardly ever see scientists.

Similarly, white scientists perceived that their black colleagues had an advantage when it came to connecting with black audiences. Furthermore, perceptions about race were frequently linked to perceptions about gender.

> **Don Cowan**: When I get up in front of a group of black school children, they will probably perceive me more remotely than they would my colleague Dr Thulani Makhalanyane. That gives him an advantage in communicating with them.
>
> **Bob Scholes**: An articulate black scientist would probably rocket to the top faster than an equally articulate white scientist in the South African situation. And, it is partly the nature of our public in South Africa. People learn better from people that they identify with.
>
> **Bruce Rubidge**: Our black students certainly get through to black school groups much better than the white students do. Cultural resonance makes a big difference.
>
> **Andrew Forbes**: At school visits, I try not to speak. I get my female or black students to speak so that the children can see that there are other role models out there apart from old white men.
>
> **Mary Scholes**: Some topics are more difficult to talk about than others, e.g. beliefs held by males about GM crops in certain parts of the Eastern Cape. Therefore, it may be very difficult for a white female scientist to speak to a black audience in the Eastern Cape. We are concerned about some perceptions of GMO crops in the Eastern Cape. But, I know that I won't be able to address those rumours with audiences there. I would have to work with a black, male scientist to engage with those farmers and consumers.

Earlier studies confirm that cultural backgrounds affect students' science learning and that it is important for educators to have a good grasp of the cultural and language backgrounds of students (Lee, 2001). Accordingly, visible scientists associated the ability of an individual scientist to connect with a specific cultural group with her/his ability to speak the relevant language of the audience.

> **Bruce Rubidge**: Language is critically important. When we need to do field work on farms in Afrikaans-speaking regions, I make a point of calling the farmers myself. I speak to them in Afrikaans and do my best to engage and excite them about the fossil heritage of the Karoo.
>
> **Francis Thackeray**: My colleague Mirriam Tawane has a PhD in palaeontology. She grew up in the area of Taung, where the 'Taung Child' fossil was discovered in 1924, representing the first specimen of *Australopithecus africanus*, described by Professor Phillip Tobias. When we address learners in that region, it is Miriam who holds centre stage when she speaks to the children in Setswana.

Importantly, Linda-Gail Bekker noted the importance for senior research team members to be present at public engagements, even if they were not the primary communicators at an event.

> **Linda-Gail Bekker**: When we talk to a community that is predominantly isiXhosa speaking, it just makes more sen*se* that somebody who speaks *isiXhosa* does that. But, even then, the researcher must be there. You must greet the audience and show your respect.

Visible scientists' perceptions that language ability was important in terms of scientists' ability to connect with different cultural groups, were borne out by a study of rural learners in KwaZulu-Natal in South Africa (Fish *et al.*, 2017). This study highlights the influence of language barriers experienced by learners during a science show, leading the authors to conclude that they need to develop isiZulu-language learning materials and presentations

However, in contrast with views that black scientists had a communication advantage in a country where public audiences were predominantly black, some visible scientists continued to perceive that black scientists faced racially based barriers in the public arena.

> **Tim Noakes**: I'm sure it is more difficult for black scientists to get on a public stage. There is still a lot of inherent racism in our society, especially among whites.

> **Amanda Gouws**: When I talk with my black colleagues, I realise that the racial stereotyping and bias in our society are still really bad. They have to work much harder to build up an academic reputation and public profile.

In particular, there was a perception that white scientists enjoyed more authority than their black counterparts.

> **Marcus Byrne**: It burns me that we will be in a mixed group of black and white scientists, and when I open my mouth, people listen to me, whereas, the black scientist have to fight a bit harder.

> **Tim Noakes**: People will trust a white scientist more than a black scientist, simply because of our history.

> **Jill Farrant**: Unfortunately, when a black scientist stands next to me on a stage, there is still a perception that she might not be as bright as me. That is really hard for me. It has to go.

Visible scientists furthermore continue to perceive the negative effects of racial and gender stereotypes, especially those scientists who are black and female.

> **Hamsa Venkatakrishnan**: Some of these racial issues are still very real. If you get up as a black speaker – even in a school – the palpable initial response is one of suspicion. You get that feeling that they think: 'This is not someone who is going to deliver for us'. So, you have to deal with that suspicion, and the surprise when you do get a message across.

> **Tolullah Oni**: There is definitely a perceived incongruity between being black and female and being an academic. The optics matter. People often say to me: 'Wow! And you're a professor!' You realise that even – even amongst young people – this is not what they expect to see.

Maluleke's account of his encounter with an audience member in Germany illustrated some of the pervasive stereotypes experienced by black scientists, not only in South Africa, but also abroad.

> **Tinyiko Maluleke**: I was giving a talk in Germany at the University of Hamburg. A German woman came up to me to thank me after the talk. She shook my hand and shoved a fifty euro bill into my hand. I wondered what that meant. There I was, a visiting professor with a very good allowance from the university. Did she think that, simply because I'm black and from Africa, I must be needy?

Some visible scientists agreed that racial barriers and stereotypes were still an issue in present-day South Africa, and that these factors would therefore affect scientists who engaged with public audiences, but they noticed a definite improvement in this regard.

> **Salim Abdool-Karim**: It used to be much more difficult for black researchers to convey ideas authoritatively, because of an inherent racial bias. As black scientists, we had to overcome that credibility gap and show that we really knew what we were talking about. Today, it is less of an issue. I don't feel it personally anymore. We have reached a point where it does not matter what colour you are.

> **Linda-Gail Bekker**: Maybe we still have some racial prejudice hangover from the past, but now we want black scientists to step forward and take opportunities.

Interviewees supported the idea that recognition for scientists, also in the public sphere, should be based on excellence, not race.

> **Salim Abdool-Karim**: We have several white scientists who are much more visible than black researchers working on HIV. No one gets the kind of media coverage that Francois Venter and Linda-Gail Bekker get, but they deserve it! It takes time to reach that level of prominence and some of the young black researchers are starting to emerge now.

> **Pumla Gobodo-Madikizela**: As black scientists, it is up to us to dispel negative attitudes. The extent to which you are able to address your topic competently will ultimately determine how people judge you. We have to stand our ground. We have to rise above stereotypes.

Visible scientists were generally aware of the desire within the science community to see young, black scientists succeed and they supported the creation of platforms that would help young black scientists to become more visible, both in the academic world and in the public sphere. More diversity in language and media outlets was among their suggestions for improving science communication across racial barriers.

> **Francis Thackeray**: I would like to see scientists who are able to speak African languages play a much greater role in communicating with audiences in their mother tongue.

> **Hamsa Venkatakrishnan**: We need more diversity in the scientists who talk to the media and they should speak to the media in their mother tongue, wherever possible. We need to hear science on the radio in languages other than English. And, instead of just commenting for *The Star* and *The Mail & Guardian*, scientists should also write for *The Sowetan*.

Six of the visible scientists I interviewed felt that race made no difference when it came to scientists communicating their work in public.

> **Anusuya Chinsamy-Turan**: Race is irrelevant. It is about the science, and the passion of the scientists who are communicating. It does not matter whether they are black or white.

Cowan referred to Chibale as an example of a scientist who, because of his excellence, was not judged on ethnicity. Interestingly, Chibale himself agreed that excellence mattered far more than race when it came to credibility in science.

> **Don Cowan**: I very much doubt that when Kelly Chibale stands on stage, anybody treats him less seriously than his white colleagues. Because he is right up there at the top – wonderful man, wonderful personality, wonderful research!

> **Kelly Chibale**: Some black scientists, including black women, are in public demand because of what they do. It is about demonstrating excellence, irrespective of race or gender.

Two scientists in the current study also indicated that in present-day South Africa, white academics faced particular challenges when it came to communicating in public.

> **Anthony Turton**: In South Africa, when white scientists step forward to advise government, a racial barrier goes up that makes the meaningful transfer of information near impossible.

> **Amanda Gouws**: In South Africa, white researchers are occasionally judged according to their race instead of what they say – something that I have experienced.

5.1.10. Population group: summary

Scientists' population group influenced their involvement in public science communication in a number of ways. For both black and white scientists there were positive and negative influences. On the one hand, racial stereotypes persist, causing scientists to perceive that audiences may be prejudiced against a particular scientists, depending on the population group she/he belonged to. On the other hand, black scientists were perceived to be better placed to connect with key audiences for science in South Africa.

Population group was therefore linked to cultural (and language) resonance, which was perceived to influence a scientist's ability to connect with a specific audience. As a result of these perceptions, scientists preferred to allocate communication opportunities to the team member who best fits the cultural profile of the intended target audience.

5.2. Attitudinal factors

The second set of factors that was explored in the current study terms of its effects on scientists' public communication behaviour related to scientists' attitudes regarding norms in science, as well as their attitudes towards the public, public communication in general, and various communication platforms. Amongst other things, their feelings about their own communication skills and the effect of personality types were also considered.

5.2.1. The influence of scientific norms

We are taught in science that celebrity fame and money somehow contaminates what you're doing – and that is just nonsense. *(Lee Berger)*

It is important to reach beyond the academic borders, even if popular communication is frowned upon in some high science circles. *(Cherryl Walker)*

In this part of the study, I assessed how scientists responded to the notions of public visibility and celebrity, and how this may influence their own behaviour in the public arena.

"We are taught all our lives to say 'no' to questions like that," Berger told me when I asked him whether he thought of himself as a celebrity scientist. "But, celebrity is not a dirty word."

The visible scientists interviewed for this study were overwhelmingly positive about the notion of public visibility, with favourable responses to the notion of their own public visibility coming from 24 of the 30 interviewees. The remaining six scientists responded in a neutral or somewhat cautious tone. Those visible scientists who were comfortable with the idea of public visibility, justified its value in a number of ways.

> **Lee Berger**: Yes, I probably am a celebrity scientist. I think that is probably manifest by the awards and prizes I have received, and the recognition from 'Time' magazine as one of the 100 most influential people in 2016.

> **Salim Abdool Karim**: I am not surprised that I'm seen as publicly visible. In 2016, I appeared in about 455 articles and news items and I was on eTV about 20 times and SABC 16 times.

Others scientists emphasised that public visibility was not important to them, and that it was not something for which they strived.

> **Bob Scholes**: I have never agonised about being a publicly visible scientist or done any kind of explicit cost-benefit trade-off analysis**.**

> **Bruce Rubidge**: I must qualify right in the beginning and say that I don't see celebrity status as an important thing in life. I don't go for high profiles. I have never done it for myself.

> **Anthony Turton**: To be honest, I have never tried to be a visible scientist. It has never been an objective that I have set for myself. I am agnostic about it.

A third group revealed some discomfort and uncertainty when asked how they felt about being publicly visible.

> **Nox Makunga**: Some public visibility is ok, but you don't necessarily want to become a celebrity scientist, because then your peers don't take you seriously.

> **Marcus Byrne**: You don't want to be the rock star, completely. You want to be seen as one of the team.

Overall, scientists in the current study were supportive of others who participated in public science communication, as has been shown by Sturzenegger-Varvayanis *et al*. (2008).

5.2.1.1. The influence of descriptive norms

When visible scientists commented on the public communication activity of their colleagues, some of them expressed a level of frustration about their colleagues' apathy in this regard.

> **Cathi Albertyn**: I have colleagues who are brilliant researchers – articulate and clever – but just not interested to talk to the media. They simply don't define themselves as people who have to educate the public.

> **Anusuya Chinsamy-Turan**: There are people who are really just not interested in public communication. They do really good work, but don't see the significance of sharing it.

> **Amanda Gouws**: Some of my colleagues absolutely refuse to speak to the media. As a political scientist, I don't understand it.

Visible scientists drew inspiration from well-known names from the history of science, and present these iconic scientists as examples of the virtues of public visibility in science.

> **Lee Berger**: Darwin did not sit in a dark room, buried in books – he was in the public eye, communicating science. So were Huxley and Einstein, and other great names in science. There was Leonardo da Vinci all the way back. All of them were celebrity scientists in their time.

Cowan mentioned Carl Sagan as a name that stood out amongst high-profile scientists, but conceded that, at one time, he had doubts about Sagan's scientific credibility.

> **Don Cowan**: I suspect that Carl Sagan was a forerunner in popularising science. I was a young student when he became famous. I have to admit, I had my suspicions about the quality of the man as a scientist.

5.2.1.2. The influence of injunctive norms

"Being a good scientist is not the same thing as being a good communicator," Bob Scholes noted during the interview, "but, just because someone goes out of their way to do science outreach, it does not mean that he or she is a bad scientist." Respondents' views on how the academic community in general felt about public science communication indicated that they were keenly aware of existing criticisms and tensions about these activities within the academic world. Several of them referred not only to science celebrities from the past, but also to the case of Professor Lee Berger in South Africa.

> **Anthony Turton**: Carl Sagan was an immaculate communicator; one of the top scientists. But, as soon he got a successful TV programme, he was shunned by science. Scientists turned their backs on him and said that he was a glory seeker. But, he communicated exquisitely to ordinary people.
>
> **Linda Richter**: Lee Berger is hammered by his colleagues for being a showman who says anything to be in the media. He doesn't get the approval or admiration from his peers that he deserves.
>
> **Tim Noakes**: Lee Berger is a brilliant scientist, but he gets so much criticism – it is just astonishing.
>
> **Don Cowan**: Lee Berger stands out as one of the most spectacular publicists – in terms of style, content and engagement. He is in front of the cameras all the time. But, I think some of the older members of the community don't quite approve of that approach.

For his part, Berger was highly critical of the concept of a set of norms governing how scientists should behave. In particular, he challenged the scientific norms related to the timing and nature of public communication about science.

> **Lee Berger**: I challenge the idea that there are norms in science. I think those are scientific mythologies that are used to degrade other scientists and cling to power. So, scientists say, to do good science, you must keep things secret and publish only in the top journals in your field. That is the norm, right? But show me a major scientific organisation and a top-end scientist who does that. NASA flew a multi-billion dollar machine by Pluto and told us there was water vapour on it within 48 hours of it passing by. How do they do that? It did not go for peer review. It was not published carefully in secret places. The papers come later, but they communicate science at the moment it happens.

Several interviewees made it clear that they did not agree with the science community's critical view of public science communication.

> **Bavesh Kana**: The academic fraternity can be incredibly harsh. They can be incredibly judgemental and prejudiced, and this can damage people.
>
> **Bob Scholes**: There certainly is the caricature of a so-called 'media scientist', or 'rock star scientist', and, you know, he is not a really good scientist. You hear those stereotypes coming out occasionally, but it is not as widespread as it used to be.
>
> **Tinyiko Maluleke**: There are all sorts of purisms around this. There are purists who will say that no respectable academic speaks or writes in public, and you stick to your field. That school of thought continues to exist, but obviously I don't agree with that.
>
> **Tim Noakes**: If you stick your head up, you're going to get shot.

Perceived 'elitism' in the academic world remained a potential obstacle in terms of public science engagement.

> **Tinyiko Maluleke**: To communicate with the public, you have to move beyond a certain kind of academic elitism. You must believe that what you know and what you study deserves to be known and understood, also by people outside of your field and outside of your narrow sphere of academic expertise. You have to believe that very strongly.

> **Linda-Gail Bekker**: Academia can be quite arrogant about how scientists should communicate. The level of the journal is what counts, and when you start moving into the public arena, you are seen as a failed scientist who could not get published in *The Lancet*.

However, several visible scientists have never, or rarely, received any negative comments from peers concerning their own public profile.

> **Bavesh Kana**: If someone has ever said anything negative about my public profile, I am not aware of that.

> **Tebello Nyokong**: Maybe my colleagues are secretly condemning my public visibility, but not one has said anything to me, so I don't know.

> **Tolullah Oni**: I have no doubt that professional jealousy about scientists with a high media profile is still an issue, but I've never heard it personally.

> **Anusuya Chinsamy-Turan**: I have never experienced any negative comments about my engagement work, but I suppose I won't give anybody a chance to say anything negative.

> **Don Cowan**: I have never had any disparaging feedback, but I suspect my public persona is not big enough to ever be a problem like that.

> **Bob Scholes**: Except for a rare comment here and there, I don't get the impression that my colleagues think I'm chasing after the media.

Some visible scientists, however, related personal experience of negative comments about their public profiles, or that they might have commented negatively on peers whom they perceived to be seeking (excessive) publicity for themselves.

> **Jill Farrant**: I have definitely experienced jealousy as a result of my media profile. Recently there was a snide comment: 'Oh, here is Mrs Bollywood coming along', after I've been in several media stories on Al Jazeera.

> **Bob Scholes**: I do have international colleagues who have that reputation as being media scientists, and I have made snide comments about them – but, only if they are the kind of scientist that shoots from the hip and always jostles to the front.

Interestingly, in her in-depth interviews with 15 Belgian scientists, Van der Auweraert (2008) similarly found that most of them experienced supportive and positive comments from their colleagues, with the exception of one scientist who experienced scathing criticism.

Based on their confidence in their own academic credentials, visible scientists frequently indicated that they were not concerned about what their colleagues thought or said about their public visibility. However, they cared deeply about their academic reputations.

> **Linda-Gail Bekker**: I'm sure I get criticised, but I easily get up on stage and it does not bother me if people think it is degrading. If another academic criticises me, I would like to see their publication list.
>
> **Tebello Nyokong**: If my colleagues criticise me for going public, honestly, I wouldn't care much about it.
>
> **Bob Scholes**: It is incredibly important to me what my colleagues think about me as a scientist. But, it hardly matters to me at all what they think about my media profile. I would like to think that my science reputation is not based on the fact that I have a public profile, but rather that it is the other way round.

Similarly, earlier studies show that scientists are becoming less concerned about negative reactions from peers and that norms regarding public communication of science are becoming less restrictive (Peters *et al*., 2008b; Marcinkowski *et al*., 2014).

By contrast to the comments from scientists who were not concerned about their colleagues' responses to their visibility, the two most visible scientists in the study, Lee Berger and Tim Noakes, indicated that they were deeply affected by this kind of peer criticism. Their comments echoed the view of Goodell (1975) that highly visible scientists are not immune to intense public and peer scrutiny, and that they often fear criticism.

> **Lee Berger**: Of course it matters to me what other scientist say about me and my public visibility. I am a human being and I have children who will read those comments.
>
> **Tim Noakes**: The worst thing was the UCT professors who wrote to the Cape Times and distanced themselves from me. To me, the way they targeted me was almost as bad as a death threat.

By contrast with peer criticism, peer support was perceived as important, even essential, for scientists who went public, especially in the case of contested topics.

> **Salim Abdool-Karim**: When you go public, support from colleagues is very important. If you are all alone, it is much harder.

Visible scientists coped with negative comments from peers in a variety of ways. It should be noted that they referred here to negative comments about the content of what they communicated (i.e. their scholarly opinion on controversial topics) rather than negativity towards their public visibility.

> **Jill Farrant**: I don't allow it to upset me as much as it did before.
>
> **Amanda Gouws**: Being older now, peer criticism does not worry me so much. I am prepared to say controversial things and to defend that. Over time, your reputation becomes stronger, and you handle criticism better.
>
> **Cathi Albertyn**: I don't take too much notice of the hate mail.

> **Linda-Gail Bekker**: There are different ways of communicating, and I'm quite happy to defend my public engagement work.

When peers or colleagues made negative remarks about scientists who are publicly visible, interviewees typically brushed these off as 'jealousy', thereby implying that visible scientists did not regard these criticisms as valid or important.

> **Dave Pepler**: Negative comments about other people's public profiles inevitably come from low performers. They can't deal with others' success because of intense jealousy.
>
> **Kelly Chibale**: If scientists make negative comments about colleagues' public profiles, I would put that down to plain jealousy. They wish they were the ones doing it. I've had comments like that, but they were not rational – purely based on jealousy.
>
> **Bruce Rubidge**: There is a certain amount of jealousy in the profession; with scientists, there always is. And so, if I am more visible than you are, you try to break me down.
>
> **Jill Farrant**: Now that scientists are getting out of the ivory tower and their work becomes more commercial, there is a lot of professional jealousy around.
>
> **Don Cowan**: Lee Berger is one of South Africa's most spectacular science publicists – in terms of style, content and engagement. Not everybody quite approves of him, but I think most of it is just envy. We are all envious of a man who has that skill.

Science communication scholars have contemplated for decades whether jealousy could be the cause of resentment from peers towards their visible colleagues (Jensen *et al*., 2008:14). Earlier studies that have revealed that scientists perceive jealousy amongst their colleagues when the scientists become publicly visible, especially via the media, include Wilkes and Kravitz (1992), Hartz and Chappel (1997) and Burchell *et al*. (2009).

In line with concerns about professional jealousy amongst colleagues, Rubidge was concerned that institutional recognition for staff who did well at public communication may fuel dislike amongst colleagues.

> **Bruce Rubidge**: There is merit in recognising staff members who do well at sharing their work with the public, but there can be a lot of resentment from people.

From time to time, visible scientists did receive positive feedback resulting from their public communication work from their colleagues. Many perceived a generally supportive peer environment in this regard, and indicated that this was important to them.

> **Amanda Gouws**: I have never had people telling me, 'Oh, you are too visible'. I get people who send me emails to express their appreciation.
>
> **Bavesh Kana**: I see a desire in my fellow scientists to communicate, so I have not heard any disparaging comments about communicating scientists.
>
> **Marcus Byrne**: I am very conscious of my colleagues' opinion and I am very grateful when colleagues say: 'Oh, I saw this or heard that – well done.' That is great. The response has been mostly positive and it is certainly important to me. I appreciate it.

> **Sheryl Hendriks**: My colleagues have been very supportive of my public science communication.

Interestingly, Soodyall and Scholes indicated that their colleagues supported their public engagement work because it meant that they (the colleagues) did not have to get involved in these activities themselves.

> **Himla Soodyall**: My colleagues have been very good about my public profile. In fact, when it comes to appearing in public, they very quickly pass the buck to me. So, they are really quite happy.

> **Mary Scholes**: My colleagues appreciate my public speaking and media work, because it means they don't have to do it. They are also quite admiring because they would probably like to do it.

These comments about positive feedback from peers reflected the views of scholars who found that, in general, the science community is becoming increasingly supportive of scientists who become publicly visible (Searle, 2011; Rödder, 2012).

Despite a positive attitude towards public visibility, some visible scientists were sensitive about the concept of 'self-promotion'. Therefore, they frequently emphasised that the credit for research, in most cases, should be attributed to a team of researchers. As such, they felt a responsibility to focus some of the public and media attention on their members of staff instead of on themselves.

> **Glenda Gray**: Self-promotion is a sensitive issue, because medical research is not done by one person. It is all about teams. The people who did the research should do the communicating. They should announce the findings. I want my staff to get the limelight.

> **Sheryl Hendriks**: I always bring in the team when we communicate – that is important. In an article for *Leadership* magazine, I insisted on a photo of the team, rather than myself. It's not about me, it is about a multi-disciplinary team.

> **Bavesh Kana**: The only way I can communicate science in public, is to separate myself from it to say this is not about me – it is about the work of my team.

5.2.1.3. Perceptions of career outcomes resulting from public visibility

Despite their awareness of the criticism on other visible scientists, and even occasional criticism aimed at themselves, none of the visible scientists I interviewed thought that their public visibility had a negative influence on their own careers, or the careers of their peers. They made it clear that their academic reputation and standing in the science community adequately protected them against any negative influence that could result from being publicly visible.

> **Bob Scholes**: My media visibility does not detract from my scientific career at all.

> **Cathi Albertyn**: My public profile has not damaged my research reputation, because in the academic audience, people know the value of my work and my reputation as a very good researcher.

> **Tolullah Oni**: For me, as long as my academic performance is on track, no one can question my public engagement work.
>
> **Tinyiko Maluleke**: The reaction from my peers has been mixed. But, because I've been a rated researcher and have built credibility over the years, it has been difficult for my peers to dismiss me. If someone criticised my public profile, I would ask them to look at my work and the recognition that I have received in the scholarly community.
>
> **Don Cowan**: I don't see any evidence that Lee Berger's career has been impacted negatively by his visibility. As far as I know, he runs a very high quality research team that is also well funded. And, he keeps getting rewards and accolades.

While visible scientists agreed that public science communication was important, they were equally adamant that scientific reputation was even more important and was, in many ways, a prerequisite for public visibility.

> **Tolullah Oni**: There is nothing wrong with scientists being publicly visible, but that is a secondary objective. The science comes first. If public communication becomes your primary objective, it can distort things.
>
> **Himla Soodyall**: There is a lot of congeniality about my public profile, but it is based on the recognition for what I have achieved in academia and my peers' respect.
>
> **Tinyiko Maluleke**: I wouldn't force scientists to communicate in public, because the first and most important calling of a scientist is to advance knowledge. We should not generalise about public communication to say it should or shouldn't be done. But, when it is done, it must be done well. To do it well, you must be (and remain!) respected in your field. You must continue with your research, supervise students, publish in the top journals and stay connected to the academic community. Then you can communicate with the public. So, it is both, rather than either/or.

These comments by Oni, Soodyall and Maluleke resonate with a comment from a scientist in Porter *et al*. (2012:417) that "communicating your science is no substitute for producing good science". In other words, public communication of science matters, but academic outputs matter more. Because of their views about the need to prioritise scientific outputs over public communication, visible scientists emphasised the need to find a balance between these activities, i.e. not to spend too much time on public visibility.

> **Linda-Gail Bekker**: You have to get the balance right – not too much of this and not enough of that.
>
> **Tinyiko Maluleke**: In terms of public engagement, the unacceptable extreme is where academics abandon their academic posts and go only public.

5.2.1.4. Normative influences: summary

Visible scientists regarded public communication of science as an important and valid activity, and most were comfortable with their own visibility in society. Some emphasised, however, that it was important to recognise the contributions of team members and to create opportunities for others to become publicly visible. Visible scientists were influenced by the behaviour of others (descriptive norms) to the extent that they drew inspiration from other highly visible scientists. However, they were not influenced significantly by the public communication behaviour of their immediate colleagues. Moreover, injunctive norms (the views of colleagues and peers) were only important to a few of them. They were generally aware that high-profile scientists were often criticised by their peers, but only a few of them had personal experience of such negative feedback. Protected by their own academic credibility, most visible scientists were not concerned about peer criticism related to their public profiles, and they did not perceive any detrimental effects from public visibility on their careers, while peer support made it easier for them to engage public and policy audiences. Protracted public controversies did affect some visible scientists on a personal level.

5.2.2. The influence of attitudes towards the public

There is a huge appetite for science and we are doing very little to satisfy it. We just don't package science stories in ways that would appeal to public audiences. *(Andrew Forbes)*

Some of our researchers want to work at the community level because they are passionate about improving people's lives. *(Sheryl Hendriks)*

In this section, I report on how visible scientists in South Africa felt about public audiences for science in the country, and how this affected their attitudes towards external communication about their work, as well as their objectives when they participated in public communication activities.

5.2.2.1. Priority audiences for participating scientists

Visible scientists generally felt that decision-makers and policymakers (in government and the private sector) were the most important target groups with whom they needed to engage, although many of them were also passionate about sharing their science with young people and children. Furthermore, they were acutely aware that it was easy to engage with science-attentive publics, while it remained challenging to reach underserved audiences. This was a point of concern.

Bob Scholes: The science geeks will seek you out and come to your lectures.

Francis Thackeray: It is mostly people who are already interested in evolution who come to public science talks, and that makes you feel that you are preaching to the converted.

Himla Soodyall: When we speak at public events, we mostly draw on the affluent sections of our society and older people – they are interested and they have time to attend these sorts of things. To change that paradigm is quite a challenge.

Anusuya Chinsamy-Turan: There are communities where there are mainly black people and we really need to reach out to children in those areas.

Further points of concern related to colleagues who did not share a passion for outreach, and funding cuts that limited outreach activities.

> **Linda-Gail Bekker**: At the heart of outreach is a belief that the masses need to be educated, and I suspect that a lot of my colleagues – especially some of the more arrogant scientists – think that this is not their problem.

> **Anusuya Chinsamy-Turan**: Because of funding cuts we are not getting to schools as much as we used to. We used to do a lot more.

Visible scientists were concerned about outreach to schools, in particular the perception that scientists were not engaging with schools most in need of science outreach activities.

> **Marcus Byrne**: The people who take me up on outreach are the posh private schools with go-getter teachers.

> **Nox Makunga**: Hardly anybody takes science talks to the township schools.

> **Andrew Forbes**: I give a lot of talks at private schools, but those children have all the resources that they need. The township schools – where learners really should hear us speak – never contact me.

> **Tebello Nyokong**: I've done many talks at schools over the years, but mostly at private schools.

It was pointed out that research sites in remote areas, outside urban areas (typically linked to fields such as palaeontology or environmental research) presented rare opportunities to engage rural learners.

> **Francis Thackeray**: It is the rural schools that don't always get the message, but those schools come to places like Sterkfontein – so it is a wonderful opportunity to engage those children.

Visible scientists with experience of working with science and mathematics teachers were particularly aware of the problems that these teachers faced, and desired to help them.

> **Anusuya Chinsamy-Turan**: Teachers really battle to make maths and science exciting to children, because they are not well enough informed themselves.

> **Hamsa Venkatakrishnan**: At our 'I Hate Maths seminars' we have an honest conversation with teachers where we acknowledge all their fears about teaching maths. We try to help them lose that knot in their stomachs by equipping them with expertise that gives them confidence.

In addition to being driven by educational objectives, scientists were motivated towards public engagement by a desire to benefit society and improve people's lives.

> **Sheryl Hendriks**: The researchers in our group who are pro-communication have a real understanding of the situation on the ground and a philanthropic desire to improving people's lives.

> **Anusuya Chinsamy-Turan**: We are not doing science for the sake of science. We are doing it for the benefit of society. That is why there is only good to be gained from going public with research.
>
> **Pumla Gobodo-Madikizela**: Caring is the most important driver of public engagement. It is about caring for the communities where you work.
>
> **Linda-Gail Bekker**: Some communities are hungry for science and want to know more about the latest advances in research.

5.2.2.2. Perceptions about public interest in science

"Don't underestimate Joe Public in terms of knowledge, but also don't underestimate them in terms of ignorance." This is how Marcus Byrne would advise young scientists in terms of thinking about the public.

Visible scientists in South Africa were aware that the public consisted of diverse segments, and that they needed to adapt their content and delivery according to the audience. Only a few of the interviewees said that they simply tried to reach the public 'in general', or the public 'as a whole'.

> **Nox Makunga**: We have such large disparities in our society. People who are educated and economically stable are very interested in science, but they don't have to worry about the basics of daily needs and survival. So, they are able to debate issues around GMOs and climate change.
>
> **Anusuya Chinsamy-Turan**: People do find science interesting, but in extreme situations – for example extreme poverty – it becomes difficult for people to think about science.
>
> **Don Cowan**: The group of people that are interested in studies on palaeoanthropology or astrobiology is not going to be the same in a rural village in Mpumalanga as in an upmarket suburb in Sandton.

In addition to segmenting audiences according to socio-economic status, visible scientists also perceived audience-based differences in terms of public attitudes towards knowledge of and interest in science.

> **Linda-Gail Bekker**: Public interest is fleeting. People have short attention spans. But, in general, people do want to know about our work.
>
> **Bruce Rubidge**: South Africans are very ill informed about science generally. They don't know much about it.
>
> **Bavesh Kana**: A large part of South African society has no idea what happens in science; they still need to become aware of the process and value of research.
>
> **Cathi Albertyn**: My sense is that a big section of society wants to know more about research, but there are also those who are happy to go with populist sentiments. I mean, we're living in a post-truth world, and Trump really came to power on prejudice rather than fact, right?

The above comments were the only ones presenting a somewhat negative view of the public, i.e. of a public characterised, at least in part, by fleeting interest, a lack of understanding and populism.

Van der Auweraert (2008) concludes that public engagement is inhibited when scientists hold a negative and critical view of the public, but most of the visible scientists in the current study did not perceive the public negatively.

Despite some reservations and qualifiers, visible scientists generally perceived that the South African public was interested in science, and that interest in science has increased over time. In general, visible scientists agreed that was it up to scientists themselves to make their research accessible to their audiences.

> **Tolullah Oni**: It is a cop-out to say people are not interested in science, because it is too complicated. We have to make it relevant and uncomplicated.

> **Tim Noakes**: The public is clever, but they need scientists to explain research to them to fully understand the latest advances.

> **Bob Scholes**: Once you get people engaged, they are interested – and that applies across all walks of life, almost without exception.

> **Himla Soodyall**: You need to know the make-up of your audience so that you can choose the language and tools that will work best for them.

Some visible scientists were intensely aware of the difficulties of making their work accessible and meaningful to a diverse public.

> **Tinyiko Maluleke**: To appeal to the general public in a manner that slowly builds a level of respectability among readers is not as easy as it looks, because they come from different persuasions, different expectations, even from different fields. So, how do you speak to all of them? It is not easy.

The practical relevance of research was perceived to make a significant difference in the public response. In particular, researchers in fields related to health and safety perceived a high level of public interest, because their topics were directly applicable to their audiences.

> **Glenda Gray**: Many South Africans have HIV or a family member with HIV. Also, we have the biggest TB [tuberculosis] burden in the world. And, then comes diabetes, and stroke, and cancer. So, of course they are interested in medical research, particularly when we have new discoveries.

> **Salim Abdool-Karim**: People are absolutely hungry for information. They read something in the papers about the healing power of turmeric, and then they start emailing me.

> **Tebello Nyokong**: People are definitely interested in their own health.

> **Nox Makunga**: When people see how science can make a difference in their lives, they become enthusiastic. For instance, the innovation to detect fires in informal settlements – that is an example of a science solution directly linked to everyday life. People embrace it.

However, scientists observed that people were also fascinated by seemingly remote topics, particularly when they related to some of the 'big' questions in science about our origins, ancestors and life histories.

> **Himla Soodyall**: I think one of the key interests people have is understanding their historical past. Now that genetics can contribute to that understanding, they want to know more. It is almost like bringing home a sense of belonging and identity.

> **Lee Berger**: In 2015, a quarter of a million South African – across all walks of life – came to view the *Homo naledi* fossils in just four weeks. People are most certainly interested.

5.2.2.3. Views on involving the public

"Your science is not separate from the society you are living in. It is a part of it. And, your science can be improved by involving society in it," Linda Richter said when I asked her about her views on public involvement in science decision-making. "We have to muddle our way through this, although it may be punishing," she added.

Visible scientists were generally in favour of the idea of involving the public in debate and decisions about science, and believed that public involvement was morally justified. Furthermore, they saw the public as potentially valuable research constituents. However, they had reservations about the availability of structures for public input.

> **Bob Scholes**: Scientists do not have carte blanche to do as they please. There are ethical and consequential considerations for scientists and for society. So, yes, the public should have a say in the governance of science. It will usually not be on a one-to-one basis, but hopefully through their public representatives and institutions.

> **Sheryl Hendriks**: We can't assume that communities are big black boxes of emptiness. They have many ideas to contribute. And, it is critical to involve them.

> **Dave Pepler**: Of course, the public should be involved in science. But, currently, the structures that invite involvement are pretty selective.

The positive view of participants in the current study regarding public input into science contrasts with earlier findings showing that some scientist feel hesitant and uncomfortable about including the public in the process of research (Thompson *et al*., 2009).

5.2.2.4. Perceived benefits of involving the public in science

In addition to other intrinsic rewards that scientists may gain from interacting directly with the public, visible scientists saw direct benefits for their own research by working with the public. Scholes and Rubidge explained how they saw the potential rewards from getting the public involved in science in a hands-on way.

> **Bob Scholes**: I am a huge believer in citizen science. In my field, some important questions can best be addressed that way. You may think that climate change science depends on big computers, but the long-term records we use were collected by people like my grandmother. She had a rainfall gauge in her garden and she recorded readings for the weather bureau

every day for many years. Nowadays, citizen science is expanding and the participants are more than mere observers, starting to take part in analyses and interpretation of data.

Bruce Rubidge: People love camping over weekends and they take books about birds, mammals and snakes with them, but they are also interested in rocks and fossils. When they go into the mountains, they really look at the surroundings and send us photos. That is how many of the important fossil discoveries are made – by the public. They alert us to certain things and then we go and have a look.

5.2.2.5. Attitudes to the public: summary

Visible scientists in South Africa were generally positive about the publics for science in South Africa, but concerned about the lack of science engagement with township and rural schools, which they perceived as high-priority audiences for science outreach. Most visible scientists demonstrated a keen awareness of the diversity of public audiences for science and the need to adapt their content according to the needs of the audience. They prioritised two diverse audiences: top-level decision-makers and school learners, clearly linked to seeking policy influence on the one hand, and providing educational inputs on the other. While most visible scientists perceived that the public was interested in science, they recognised that it was harder for some sectors of the South African society to engage with science topics than for other sectors. Visible scientists were mostly positive about involving people in science, but thought that South Africa lacks structures and mechanisms to involve the public meaningfully in public science debates and decision-making.

5.2.3. Attitudes towards public science communication

Over time, I saw the power of people who can communicate. *(Tolullah Oni)*

Public communication should be an intrinsic part of every research activity. *(Linda Richter)*

It is reasonable to expect that scientists' attitudes towards public science communication would shape their involvement in these activities. Relevant findings are reported here. The predominantly positive attitude of my study participants towards public communication of science resonated with findings from Abreu *et al*., (2009). That study finds that academics in the UK are generally positive about public communication and engage with society in multi-faceted and nuanced ways.

5.2.3.1. Rationale for public communication of science

"You mean, apart from masochism?" Tolullah Oni replied jokingly when I asked her what motivated her towards communicating her research with public audiences. "Asking me why I communicate science is like asking me why I breathe," was how Bob Scholes responded to the same question. "It is part of who I am. It is a given."

Given that the scientists interviewed during the current study were identified by a panel of science-media experts as being publicly visible, it was to be expected that they would view public communication about their work as a meaningful and worthwhile activity. This was indeed the case. None of the visible scientists in the current study had a derogatory view of public communication, and none of them perceived it as a stigmatised activity. They were, however, aware that some other scientists were more critical of public science communication.

As suggested by the behavioural theories that underpinned this study, the communication objectives (or intentions) of visible scientists have a direct bearing on their behaviour. It was therefore important to question them about what they hoped to achieve when they stepped out to engage with audiences other than their colleagues and peers.

Their responses to my question about the rationale for public communication of science illustrated that the participating scientists had many different reasons for regarding public engagement as an important activity, and that they had a wide range of objectives in mind when they communicated outside the academic world. The objective of giving something back to society was uppermost in the minds of most visible scientists, followed by objectives such as looking for funding, policy influence, demonstrating value to the tax payer and contributing to public education. The goals of giving something back to society and contributing to the public good were mentioned along with goals such as helping to educate people, combating misinformation and being a role model that inspires a new generation of scientists. These findings echo research that shows that scientists and research organisations are increasingly aware of the need to communicate science more effectively in the public arena as a way to counteract potentially dangerous misconceptions and misinformation spread by lobbies with vested interests (Hunter, 2016). Scientists' motivations for contributing to the public good and demonstrating to the taxpayers that research money was well spent, were also closely linked to a perception that they have a duty toward the public to communicate.

5.2.3.2. Altruistic goals

"I want to give people hope," Farrant said about why she loved to communicate about her work on drought-tolerant crops, "and I want to live up to my reputation as a rock 'n' roll scientist that breaks down the stereotypes about women in science".

Most of the goals that visible scientists mentioned related to serving society in one way or another, whether through education, alleviating the burden of disease or helping people to make informed decisions. Scientists frequently mentioned that, in a democratic society, people had the right to access scientific information, particularly in the case of publicly funded research. Consequently, interviewees were frequently motivated towards public engagement by a desire to democratise science and serve society with their expertise.

> **Tinyiko Maluleke**: We live like monks in libraries and underground archives – but we should be reaching out to *society* and tell them what we are doing; how we are solving problems in the lab, but also on the street. Whether you are talking about traffic, domestic violence or a new insect attacking crops in Limpopo – we have to solve those problems, but we must also be seen to be solving those problems.

Bob Scholes: The bulk of science done today is 'Mode 2 science' – responding to problems posed by society, executed by scientists, and then reported back to society. Unless you close that loop, you might as well not have done it. It is a big challenge to develop a relationship of trust between science and society. We have to convince people, including policymakers, that science is not a threat – it is a resource to be used. We have to make it clear when and how they can call on scientific expertise, and how they could use it. All of that is work in progress, and it's a slow process.

Lee Berger: The people who pay for the science, deserve to understand it. It is especially critical to communicate when you work in a field – like biology – that have complexities rooted in society and religion.

5.2.3.3. Educational goals

Across most of the interviews, a desire to educate and excite the public emerged as a key driver for visible scientists to spend time with public audiences. Educational goals were also linked to a desire to influence public opinion and behaviour.

Linda-Gail Bekker: Our population needs to be educated more than ever before; there is quite a knowledge gap.

Anusuya Chinsamy-Turan: It is important for young people to understand the possibilities of careers in science.

Lee Berger: The natural world is exciting and adventurous, and sharing the process of discovery with them may lead young people into directions they might not otherwise have considered.

Bruce Rubidge: In this time of biodiversity crisis, people need to realise the effect that humans have on Earth.

5.2.3.4. Strategic goals

We scientists are our own worst enemies, because we think what we do is important, and we don't explain it to people, and then – when we are looking for support – we don't understand why we are given such limited resources. *(Kelly Chibale)*

The reason we have disasters in the US such as the disbelief in evolution and collapse in scientific funding is that scientists live in a bubble and that they are too arrogant to communicate. *(Lee Berger)*

Most visible scientists interviewed saw a direct link between public communication of science and public or political support for science. Given this perceived link between communication and support, many visible scientists pursued strategic objectives, in particular funding, when they engaged external audiences. In other words, they saw public platforms as opportunities to gain public and political support. These goals resonated with earlier studies showing that scientists are keen to raise the profile of science and increase their own relevance via public communication (Braun *et al*., 2015; Grand *et al*., 2015; TNS-BMRB, 2015).

Marcus Byrne: I am astonished at the support we get for science in this country. And I am really grateful. And we just have to keep feeding the right guys the right ammunition to keep the government paying us and allowing us to do good science.

Kelly Chibale: Our leaders need to understand the value of science, because they make the decision about investing resources in science. Today's world is about a knowledge economy. We can't have a knowledge economy without scientific skills. That is non-negotiable.

Bruce Rubidge: If you want your science to continue, you need to tell people about it, to attract interest and new students. In paleo sciences, a lot of our success is based on our efforts to tell people about our research.

Glenda Gray: We hear all the time about how our tax money is squandered. So, it is important that – in the case of research – the taxpayer sees value for money. Health can change the lives of South Africans, and if I believe that, it is my job to raise funding for health research. If I do not bring in money, I am not doing my job as the president of the MRC.

Jill Farrant: I have world-class collaborations underway. We are aiming now at the Bill and Melinda Gates Foundation. I hope that our combined profile may be enough to drive this.

Tim Noakes: My funding came from public visibility – I worked on it for 30 odd years. You influence individuals, and those individuals become leaders of industry, and that's how the money flows.

Linda-Gail Bekker: To sustain policy buy-in and to keep the funding going – that is the most important reason why we run the International Aids Conference every two years. We invite every type of media you can think of, including the *Washington Post*, the *New York Times*, the BBC, CNN ... they are all there. We get celebrities. At the 2016 conference in Durban, we had Prince Harry, Elton John, Bill Gates, Princess Mabel ... you name it, they were there. Charlize Theron, too. And these celebrities suck in the media. We would be stupid not to use such an opportunity well – so we show them the fantastic things we have done, but also remind them that HIV is still a huge challenge with many aspects of the disease still unsolved. We tell these stories to the media, so that they can take it to the broad, global community. And it is powerful! And, if there is a community outcry, then the politicians and funders say: "OK, we need to put money into this".

From these comments by Gray, Noakes and Bekker, it is clear that they do not perceive any problem with focusing on the objective of fundraising when they communicate with external audiences. This contrasts with earlier research and opinions that many scientists do not regard seeking publicity for monetary gain as a respectable endeavour (DiBella *et al*., 1991; Weingart & Guenther, 2016; Weingart, 2017a). In the current study, Berger also said that money was perceived as a "dirty word" that scientists should not talk about.

5.2.3.5. Defensive goals

Visible scientists were aware that misinformation in the public sphere presented a challenge for the public communication of science, and this further motivated them to engage with public audiences. Accordingly, Dudo and Besley (2016) show that these defensive goals are major drivers of scientists' public engagement efforts.

Cathi Albertyn: We live in a world where people are so happy not to know the truth. One of the real dangers facing our world is the Trump danger – the uninformed and misled public.

Salim Abdool-Karim: Making sure information is accurate and trying to correct some of the misinformation out there – those are major reasons for scientists to communicate.

Lee Berger: Much of society's belief systems are based on mythology, alternative facts and other things that can be harmful – not only to individual humans, but also to the other living organisms on this planet and the planet itself.

Marcus Byrne: We are full of untruths in this world – either deliberate and devious or just complete naivety or ignorance – and it is up to us, scientists, to help seek truth to explain things around us.

5.2.3.6. Feelings about advocacy in science

I asked the visible scientists in this study how they felt about becoming advocates for a certain policy position in science, and whether they saw themselves playing a role as public advocates. Most interviewees had no problem with being active and visible as advocates (or even activists) for a certain policy position, but some were more cautious. One thing on which they all agreed was that, when scientists argued a point in public, their arguments always had to be based on credible evidence, not emotion.

Cathi Albertyn: Scientists can and should become advocates when circumstances demand it. Whether you fight against Aids denialism or climate change denialism, people are arguing for certain regulations and agreements on the basis of science. The same is true for a whole range of human rights issues. We can never be completely neutral in advocating a particular cause, but we have to argue on the basis of facts and research – not emotion – and we must be prepared to engage the other side.

Hamsa Venkatakrishnan: In the South African tradition, some scientists quite overtly call themselves activists and I don't think it is a problematic position to take, as long as the advocacy stems from a research base. Personally, I prefer to take [a] strong academic position in the public conversation, rather than an activist position.

Linda Richter: As scientists, we have a moral obligation to speak up about things that are not right in our society, and to ensure that – where relevant – our research actually influences policy.

Cherryl Walker: One could argue that all scientists are advocates, even if they don't recognise it. Physicists may think they are just doing pure science, but actually they are advocating a world view as well. I don't see a problem with taking a position, as long as you can motivate it and also listen to other points of view.

Glenda Gray: Why would scientists be scared to be activists? You have to speak out about what you are passionate about, as long as it is evidence-based.

Some scientists were noticeably wary about a closer coupling between science and politics and therefore more cautious in their approach. Most agreed, however, that there was a role for some, if not all, scientists to play when it came to science advocacy.

> **Lee Berger**: I am surprisingly divided in my mind about advocacy for science, because I am very nervous about the politicisation of science.
>
> **Marcus Byrne**: There is a danger that you can become a crusader for a cause, which I don't want to be. But, if you feel passionate about something and you have the evidence, you should do it.
>
> **Sheryl Hendriks**: I am cautious about advocacy. I can speak about the evils of sugar, without actually advocating for a sugar tax.
>
> **Bavesh Kana**: The advocacy space is an interesting space to be in, but we should not force scientists if they are uncomfortable in that role.

Visible scientists were generally concerned about global political changes that affect science and that have ramifications for public communication of science, with several expressing unease about President Trump (the current president of the United States) and his policy directions.

> **Anthony Turton**: Donald Trump is fundamentally changing the international dynamics. He is pushing America back into an isolationist mode, and more importantly, he is isolating and undermining scientists. He has as a stated objective the weakening of the Environmental Protection Agency [EPA]. So, he has put at the head of the EPA a man whose objective it is to dismantle the EPA, or to reduce it to just clean water and air and nothing more. So, I would argue that globally there is an attack on science, and I would link it up to the broad emergence of populism in Europe and other parts of the world. It even extends to South-East Asia, if you look at Duterte who is emerging as a populist leader in the Philippines. All of these people are science sceptics.

As in South Africa, scientists around the world are taking note of the rising tide of populism and this has resulted in increased interest in the role of scientists to speak out and advocate for science and evidence-based governance in the public sphere (Williamson, 2016; Besley & Dudo, 2017).

5.2.3.7. Positioning of public science engagement within science careers

My question to visible scientists about where they placed public communication as an activity relative to their other duties and tasks, revealed that most of them saw public communication as an integrated component within their academic roles. They also felt strongly about the importance that fellow scientists should become more aware of the need to integrate academic work and public communication.

> **Himla Soodyall**: Communicating with the public is a core part of being a scientist.
>
> **Amanda Gouws**: For me, there has never been a separation between academy and real life.
>
> **Anusuya Chinsamy-Turan**: Every research project I do has public communication built into it.

Tinyiko Maluleke: It is important that more scholars recognise this as a required discipline, as part of what they are expected to do.

Linda-Gail Bekker: Scientists should make public engagement part of their research instead of an optional add-on activity.

Tolullah Oni: Public communication is a core part of what we do.

Mary Scholes: It is core to my job.

Salim Abdool-Karim: It is an essential part of my role.

Linda-Gail Bekker: I think it is an absolutely critical part of the work I do. The cycle of good research requires a dissemination piece at the end.

Those who integrated public communication into their research plans frequently indicated that they routinely planned and budgeted for these activities as part of their research projects.

Kelly Chibale: We plan for it. We have our own media person. We have a budget set aside for communication.

Lee Berger: You absolutely have to plan for communication from the start of every project.

Bob Scholes: In big projects, we routinely put aside a fraction of the budget for public communication. Depending on the nature of the project, 5% of the total budget is not at all unreasonable. The key thing, of course, is not to put that at the end as an add-on. You need to integrate communication from quite early in the project. For some projects, I would argue that a much bigger fraction of the budget is warranted – at least 20%.

Many visible scientists shared the view that, collectively, scientists should become more pro-active and visible in the public sphere. While some scientists indicated that they planned ahead for communicating with public audiences, most admitted that they were mostly reactive in this regard: responding to opportunities, rather than instigating contact themselves.

Tolullah Oni: I think, as scientists, we are much too reactive. Scientists sit in their ivory towers and wait for someone to ask for their expert opinion. And then we wonder: why are there no scientific voices out there? We wait for a crisis and then we say 'Ah, they should have listened to us'.

Don Cowan: Public engagement elements are things that crop up. These things are a little bit like mushrooms – you never know when the next one is going to appear. Although, I would admit that it is a huge weakness that we don't have a plan or policy for this. It is not an unrealistic dream to think about public communication from the start of a project, and then plan and budget for it. It certainly could be done. But, it is not the way that we think – even, I suspect – those of us who are better imbedded in public awareness than others.

Cathi Albertyn: My public appearances are mostly in response to requests. We are far too reactive, we must be more pro-active. In the area of women's rights, we should pro-actively write columns and opinion pieces, but we are not good at doing that.

Similarly, in her study of Belgian scientists, Van der Auweraert (2008) found that most of the scientists were willing to participate in public communication of science if they were invited to do so, but would not take the initiative to create these opportunities themselves. This implies that many scientists may have a positive attitude towards public communication, but will never participate themselves if they are not offered a ready-to-use opportunity or platform to do so.

Visible scientists were furthermore aware that many scientists, if not themselves, saw public communication as an optional activity, viewed and judged separately from their scholarly duties.

> **Tinyiko Maluleke**: For many people, this is weekend work; after-hours work. It is extra work, but not crucial work. At the end of the day, when you are tired, to have to write a popular article – it is hard. Why would you want to do that? It feels like a waste of time.

5.2.3.8. Preferred ways of engaging with public audiences

> ***Recently, for World Elephant Day, I was in the field – elephant dung in the one hand, dung beetles in the other hand – and a group of people around me. It was just brilliant!*** *(Marcus Byrne)*
>
> ***I feel really strongly that good research includes dissemination to the public. The people for whom this really matter don't read*** **The Lancet*, you know. So, to reach that man and woman on the street, you have to talk to a newspaper, present a public lecture, write a blog … or find a way to get your findings out there.*** *(Linda-Gail Bekker)*

Scientists' public communication behaviour and their associated attitudes become visible in the public engagement activities in which they choose to participate. Van der Auweraert (2008:72) describes these activities as "mirrors" of scientists' views about public communication, and the objectives they have in mind when communicating. Consequently, I asked the participating scientists about their preferred channels for public interaction.

The scientists I interviewed used a range of platforms for public engagement, as illustrated in Figure 5.1. They indicated a preference for communicating via the mass media (print, radio and television), but also valued the opportunity to interact with small groups, including patients and learners. They enjoyed public speaking, and some of them found social media channels increasingly useful. These findings were in line with results from earlier studies showing that senior academics favour mass media exposure for their work and that they are sought after as journalistic sources (Kreimer *et al*., 2011; Bucchi & Saracino, 2012). Notably, more than a third of the interviewees mentioned a preference for interacting with small groups of people. Their comments illustrated that they valued the feedback from and interaction with members of the public. In other words, they subscribed to a dialogue approach, which is widely perceived to be a more meaningful way of interacting with the public compared to a top-down, one-way communication style (Nisbet & Scheufele, 2009).

> **Glenda Gray**: I like talking to the people who are participants in trials – trying to understand what they think about the research.
>
> **Linda-Gail Bekker**: I love to be in a room with people and feel the interaction.
>
> **Kelly Chibale**: I prefer to talk and engage directly. In this way, you do not get misunderstood easily.

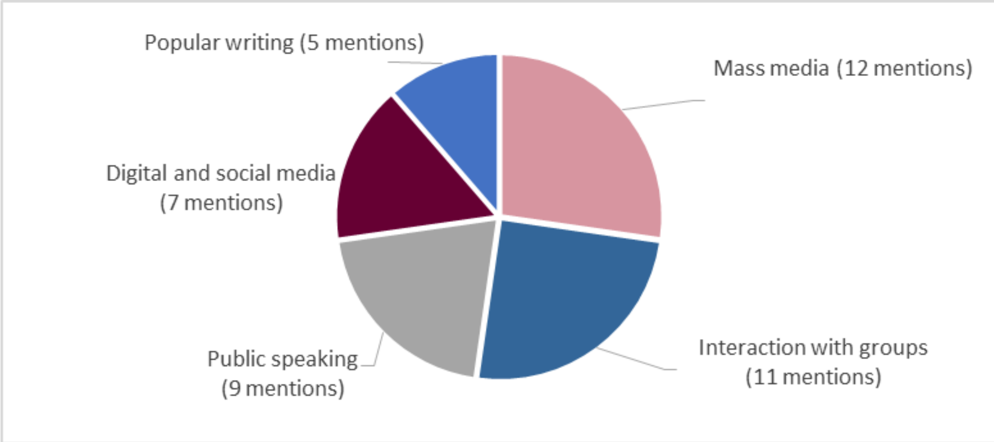

Figure 5.1: Participating scientists' preferred communication platforms

Van der Auweraert (2008) found that most scientists who responded to her study preferred dissemination-style activities, such as public lectures, newsletters and media interviews, with only a minority mentioning interactive activities. Van der Auweraert notes that her respondents used verbs such as 'speak', 'distribute', 'inform', 'tell' and 'show' to describe their own public communication activities. These words typically describe one-way interactions, while relatively few of the scientists in Van der Auweraert's 2008 study used transactional verbs such as 'debate', 'interact', 'discuss', 'participate'. Contrastingly, scientists in the current study frequently used words such as 'engage', 'interact', 'chat' and 'listen' when I asked them about their favourite type of public science engagement. Interaction and dialogue also emerged as preferred modes of public engagement in a study of UK scientists (TNS-BMRB, 2015).

In Figure 5.2, I provide a visual representation of the most frequently used verbs used by visible scientists to describe their preferred ways of communicating with public audiences. This visual demonstrates the prominence of two-way communication ('interact' and 'engage') over one-way communication (such as 'write' and 'talk'), as it emerged in the current study.

Figure 5.2: Verbs used to describe preferred mode of public communication

Visible scientists' comments about public speaking further demonstrated why they valued the presence and feedback of the audience.

> **Lee Berger**: I enjoy the visual connectivity I get from speaking to people and telling a story. I love to see how the audience responds. I can stop and clarify. I have more control over it. With all other media – from an interview to a Facebook post – once you have sent the information out, you don't have that immediacy of interaction with the audience.

> **Tolullah Oni**: With face-to-face communication you can read the audience in real time, and you can adapt what you communicate.

These findings suggest that visible scientists in the current study valued interaction and dialogue with public audiences, which contrasts with findings of the general population of scientists in other countries showing that they mostly see public communication as a one-way dissemination of information, i.e. predominantly communication according to the deficit model (Davies, 2008; Holliman & Jensen, 2009; Casini & Neresini, 2012; Namihira-Geurrero, 2016).

Several interviewees referred to using a narrative as a tool when they communicate with public audiences. This demonstrates an awareness of the power of storytelling.

> **Bruce Rubidge**: I like to tell people the fantastic story of the South African fossil record.

> **Francis Thackeray**: I believe that, after many years of clamping down on the teaching of evolution in this country, a new story has to be told.

> **Himla Soodyall**: Sometime science communication is about storytelling – sharing personal experiences. People find that endearing.

> **Pumla Gobodo-Madikizela**: Connecting with artists, we can become more creative and use different forms of communication to tell the story to a wider audience.

Scholes told me that 'the fireside chat' was his favourite type of public engagement.

> **Bob Scholes**: I spend a lot of time with groups of people in the bush as a professional guide and trainer of honorary rangers. By far, my favourite engagement tool is 'the fireside chat'. I love it and I think I do it really well. It is a primal form of communication. It is about stories and it is as old as humankind. Sitting around a fire, talking to people – that is hard to beat. So, we don't teach in a classroom – we do it in the bush … in a circle, under a tree. It breaks down the 'talk-and-chalk' idea. We get rid of the setting that says, 'I'm the big guy; you're the small guy'. In that way you get around many of the problems associated with other forms of communication.

Scholes's story illustrates the kind of interaction that puts the expert and audience on the same level and breaks down some of the barriers in order to promote interaction.

5.2.3.9. Visibility triggers

"When I won the L'Oréal Award,[62] paparazzi were chasing after me for photos. It was insane!" Jill Farrant said when I asked her whether there was a specific event or person that prompted or heightened her public visibility. "Also, when I did the TED[63] talk, I had to get used to lots of cameras and all the trappings of sound and stage equipment, and I was completely gob-smacked by the idolisation that went with it," she added. As in the case of Farrant, other visible scientists described winning a major international award or doing a very high-level public talk as a life-changing experience that transformed the way they viewed public science engagement.

The scientists to whom I spoke were furthermore propelled towards public debate when they felt obliged to oppose a specific point of view. Several visible scientists therefore traced the roots of their current public profile back to their social activism in the past.

> **Salim Abdool-Karim**: When Thabo Mbeki announced his denialist position on HIV/Aids, I could not stay quiet. We had to give the alternate side in a very clear and succinct way, and that got me close to the media.
>
> **Glenda Gray**: I was outraged about people, because the government would not give AZT[64] to pregnant women. From there I morphed into an outspoken scientist who had credibility because of my earlier involvement in activism.

Several more influences and events triggered interviewees' involvement in public engagement about their work. For example, Soodyall credited the influence of a mentor.

> **Himla Soodyall**: Trefor Jenkins[65] played a huge role in my involvement in societal engagement. I moulded myself on his example to gain the confidence I needed to speak in public. I was a very different person before that.

A scientific breakthrough that hits the headlines could force scientists to get used to media attention in a very short space of time.

> **Kelly Chibale**: I was thrust into the public domain when our discovery of a new malaria drug in 2012 made headlines locally and around the world. We had international partners, but it was an African-led initiative and it got a lot of attention.

Scientists also become enthused about public engagement by being invited to get involved and given a platform.

[62] An international award for women who excel in science.

[63] TED is a non-profit organisation devoted to spreading ideas in the form of short, powerful talks

[64] AZT is an antiretroviral medication used to prevent and treat HIV/Aids

[65] Born in Wales, Trefor Jenkins spent most of his working life as a human geneticist at various research organisations in South Africa – see http://www.samj.org.za/index.php/samj/article/view/7627/5695

> **Marcus Byrne**: Someone contacted me purely by accident and said they wanted to start some insect activity for kids at the Johannesburg zoo. It just captured me and 'Yebo Gogga'[66] is now extremely popular.

Contact with journalists, which often results from public events, provided a springboard for ongoing media involvement.

> **Tinyiko Maluleke**: I was speaking at a graduation event at the University of Limpopo when an SABC reporter came to me afterwards and asked me whether I would be willing to come to the studio to talk about the kind of things I said in my address. At first I did not understand why he wanted to talk to me, but that was the start of years of talking on radio.

From their responses, it was evident that many visible scientists started their public engagement activities modestly: by doing a talk at a local library, garden club or scientific society. These were almost always remembered as positive and enjoyable experiences that gave them the confidence to speak in front of bigger audiences. The 'snowball effect' (one public appearance resulting in more invitations from audience members to speak at a different venue and so on) then provided them with further opportunities. However, once scientists became visible in the public sphere, they were repeatedly invited to comment on issues of the day and speak at public events. As Cherryl Walker said, in a country such as South Africa "visibility begets visibility" because "a fairly small circle of people are seen as thought leaders".

5.2.3.10. Attitudes to public science communication: summary

Visible scientists in South Africa shared a positive view of public science communication, but they were motivated to participate by diverse objectives, including educational, strategic and defensive goals. Given concerns about the influence of global political changes regarding science, and the perceived need for increased policy influence from research, most visible scientists were prepared to take on an evidence-based advocacy role in science. Public communication of science was a core activity for most visible scientists, with a few of them considering it an optional or additional activity. Very few of them, however, pro-actively planned and budgeted for these activities. Visible scientists valued both mediated and direct forms of engagement. Mass media interviews and face-to-face interactions, especially in small groups, emerged as the preferred platforms for engaging with the public.

5.2.4. The influence of attitudes towards mainstream media

Journalists think differently to the way scientists think, and they have a job to do. *(Jill Farrant)*

At our own peril, we dismiss journalists. *(Linda-Gail Bekker)*

[66] A public science engagement event held annually at the University of the Witwatersrand

Historically, mass media have been regarded as the most important means whereby scientists became publicly visible, and it remains a key platform for public communication of science.

5.2.4.1. Relationships with mainstream media

Two thirds (20 out of 30) of the interviewees in the current study described their relationships with local science journalists as largely positive. Of the other ten, five relayed both positive and negative experiences resulting in mixed feelings about the media, while five were predominantly negative about their mass media interactions. The mainly positive responses reflected recent international findings that interactions between scientists and journalists are becoming more frequent and more constructive than before, and that scientists are generally motivated to work with the media, as well as that they have particularly high expectations of media interactions (Pitrelli et al., 2006; Peters *et al*., 2008b; Peters, 2013).

The high-profile scientists in the Goodell (1975) study were deeply aware of the power of the media and they were keen to use it for gaining visibility and influence. Similarly, the visible scientists participating in the current study regarded journalists as crucial partners and particularly appreciated the amplification value that media exposure brought to their public engagement efforts.

> **Glenda Gray**: Working with the media makes it possible to tell good stories that give people hope – for example telling people that we are working on an HIV vaccine.
>
> **Marcus Byrne**: When there is media attached to public activities, the ripple effect is much greater. Instead of talking to 20 people, you are talking to 2 000 or even 20 000. It makes it all worth doing.[67]
>
> **Francis Thackeray**: The media plays a crucial role in communication about our fossils and making the work of great scientists – like Phillip Tobias – known to society. My relationship with the media has been very positive over many years.
>
> **Anthony Turton**: Journalists are vital partners in the communication of science in this complicated world that we live in.
>
> **Linda-Gail Bekker**: The media are absolutely key to everything we do. No publicity is bad publicity. I refer to myself as a media slut.
>
> **Bavesh Kana**: Journalists are the ones who get the message out there, so they are the link between the science I am doing and the community. Journalists are part of the solution; they play a pivotal role.
>
> **Amanda Gouws**: I make time for the media, even if it eats into the time of other things that must be done. It is important enough to me.

[67] This comment by Byrne is reminiscent of what Ehrlich said to Goodell (1975:20), “Any loudmouth, if instead of talking to 200 students at a time, can talk to 200 000 over radio and TV, is obviously going to take the opportunity.”

The comment by Bekker where she refers to herself as a “media slut” is interesting, since earlier research shows that many scientists are concerned about being viewed as “media tarts” or “prostituting” themselves to the media (Burchel *et al*., 2009:62).

Some of the interviewees indicated that they were aware that not all scientists were keen to work with journalists, but they emphasised the importance of constructive collaborations with the media that complied with the needs and time pressures of the media. Similarly, Peters *et al*. (2008b) found that scientists are increasingly willing to adapt to media logic and demands, especially when this helps the scientists to achieve their own communication objectives.

> **Kelly Chibale**: As scientists, we need journalists. When you get media attention, be grateful, and use that opportunity to communicate. I have never turned down an interview, I am always ready to talk to reporters. I realise that actually I am a servant, I need the attention. I don’t see it as the people are bothering me. They are giving me an opportunity to communicate what I do and I take it as an opportunity. I don’t take it for granted. I see it as a blessing.

> **Bruce Rubidge**: Scientists often see journalists as a nuisance and shrug them off. I don't think that is right. Scientists must make time for journalists and try to be available.

Glenda Gray was a good example of a top scientist who worked hard at overcoming her self-acknowledged stress and fears of media interaction, and wanted to nurture a constructive relationship with journalists. Her three top rules for interaction between scientists and journalists illustrated that she respected and valued the media:

> **Glenda Gray**: Never say ‘no comment’ and never ever ignore a request from a journalist – that is rule number one. Secondly, never be rude, arrogant or aloof; never approach a journalist with a high-and-mighty attitude – that just pisses them off. And, thirdly, always tell the truth – be as honest and authentic as possible.

Gray and other participating scientists frequently described their interactions with journalists as mutually beneficial trust relationships that had been nurtured over many years.

> **Glenda Gray**: It takes a long time to build trust with the media, but it is incredibly important.

> **Pumla Gobodo-Madikizela**: I have a relationship with the op-ed editors in the newspapers where I submit my views, and that is important. When I submit a piece, I know they value my opinion and they want to publish it.

> **Linda-Gail Bekker**: Journalists are allies who can actually enhance what we do. So, I do my best to cultivate and nurture those relationships. It takes effort, but it is worth it. I always answer their questions. But, in return, if I have something interesting, I call them up and they come round and they will print what I want to put out there.

The visible scientists participating in the current study demonstrated an understanding of the needs and constraints of the media, and were typically tolerant of some of the errors that do occur when journalists reported on their work. Goodell (1977) came to the same conclusion: visible scientists are not blind to the faults and inaccuracies in reporting by the media, but they are tolerant of these failings and handle them well.

> **Bob Scholes**: If a mistake in the media happens, I ask myself: 'Did it substantively change the message?' If not, I just let it go. I don't get hung up about it.

> **Jill Farrant**: I have always had a really cool relationship with journalists. They are interested in what I do.

> **Don Cowan**: My media experiences have been mostly very positive. The material that comes from interviews is typically pretty accurate. In many cases correspondents have sent drafts for review which allows you to correct any minor issues. What I have seen is that – as these things get filtered – they get diluted a bit.

> **Marcus Byrne**: Occasionally something gets mangled and misreported. And it is a bit annoying, but I see that as part of the deal.

The nature of visible scientists' relationships with journalists was further demonstrated by the fact that they knew some of them well. The names of a few science and health writers (Elsabé Brits, Sarah Wild, Katherine Child and Tamar Kahn) were mentioned repeatedly. Interestingly, more than one interviewee referred to their relationship with the late Christina Scott, a renowned science journalist who died in a car accident in 2011, which was testimony to her influence and legacy.

> **Tebello Nyokong**: I love journalists, but my favourite will always be Christina Scott. She was the one who taught me how to use five minutes for maximum impact.

> **Anusuya Chinsamy-Turan**: Christina Scott was passionate about science. My luck was that she also was crazy about palaeontology. I really learnt a lot from Christina, such as how to write a press release, which she was able to do with such flair. She thought differently about making science exciting. Sometimes, when I prepare a popular talk, I still hear her voice telling me, 'Surely, you're not going to say it like that, are you?'

Reflecting on their interactions with journalists, some visible scientists mentioned that they have had very diverse experiences, both positive and negative. Their negative experiences related mostly to the impression that the journalists were not well prepared for interviews and that they were not really interested in the subject matter.

> **Pumla Gobodo-Madikizela**: Journalists come in different shades. Some of them do not prepare at all and want you to write the story for them. They use the interview as the starting point and your name is thrown in here and there. This is discouraging. But, other journalists do their research before they see you and they know exactly what questions they need to ask you to fill in gaps in the story. I find that very inspiring. It makes the scientist feel respected.

> **Anusuya Chinsamy-Turan**: Some journalists come prepared, while some expect the story to unfold while they are speaking to you. I immediately know when I am talking to a good journalist who is interested in what I have to say. And, I know when I am talking to somebody who is just looking for a story that they are not interested in themselves.

Bruce Rubidge: Elsabé Brits from *Die Burger*[68] is just outstanding. She understands her subject, she understands her audience and she understands the scientists. So, when she comes for an interview, she is not wasting your time. But, some journalists come in here who have done no preparation and actually have no interest in the topic. They are a pain.

Linda Richter: I have had very bad experiences on live, phone-in radio programmes where we are expected to answer every single question about human behaviour. People phone in and ask, 'Why do people like chocolate so much?' Well, I have no idea! And, when the interviewer is not prepared or skilled enough to steer the situation, the scientist ends up in a very uncomfortable situation.

When scientists perceived that journalists were not prepared for an interview, they (the scientists) adopted a range of measures to take control of the situation in order to ensure a more satisfying outcome for them.

Mary Scholes: Frequently, journalists ask really superficial questions. So, I usually insist that they send me the questions in advance so that I can modify them to suit the audience.

Cathi Albertyn: What I hate the most is when a journalist has a prepared set of questions that they ask one after the other. They don't listen to your answers, they just ask the next question. A good journalist will hear what you say, and respond to that.

In addition to a lack of preparation, journalists' deadlines and demands for short answers emerged as key difficulties in the relationships between scientists and journalists.

Cherryl Walker: I find it really difficult to work with journalists because of their sound bite culture. They are always in a hurry, they have a deadline right now and they want a pithy quote. This is really challenging when you are talking about a topic that requires a more extended reflection.

The issue of who has the final say over the content of a story remained another point of contention between scientists and journalists. This is similar to findings from earlier studies (Gunter *et al*., 1999; Peters, 2014). Studies show that while journalists generally do not feel that they are obliged to let scientists check their stories, scientists typically expect this to be the case (Massarani & Peters, 2016). Similarly, interviewees in the current study generally framed their interaction with the media positively, indicating that journalists allowed them to approve copy before going to print, and viewed it negatively when journalists did not follow this route.

Mary Scholes: On the whole, South African science journalists do try to get the story right. And, they are very responsible in sending you the text beforehand.

Cathi Albertyn: The best print journalists are those who quote you properly and send the copy for checking. I have been misquoted, so I insist that I see it in writing, but I don't always get it.

Sheryl Hendriks: Most journalists work with you to improve the copy and they come back and check facts, so it has mostly been positive.

[68] *Die Burger* is a daily newspaper in the Western Cape, South Africa – see www.dieburger.com

> **Bruce Rubidge**: If Elsabé Brits writes a story, she would probably send it to me, because she is so diligent.
>
> **Tolullah Oni**: In my experience, when journalists are not certain about the facts, they check back with me to make sure.
>
> **Amanda Gouws**: I always ask to see the story, but I don't always get it. But most journalists know that it is important to give me final input.
>
> **Andrew Forbes**: Very few science journalists would give you their story to proof before they publish it. As a result, I've had many bad experiences.
>
> **Marcus Byrne**: I ask to see the copy, but I don't insist. The journalists never disagree, but they often don't deliver.

Some visible scientists also indicated an awareness that, even when they approved the final story written by a journalist, the story could (and often did) change before it was printed.

> **Linda Richter**: It is not a practise of journalists anymore to return your stuff. And they have no control over changes made by sub-editors. So, they end up apologising to you once the story is printed, saying: 'I am so sorry, the story in the paper is not what I submitted and I know it is not what you said'.

My data showed that scientists' decisions on whether or not to insist on reviewing a story a journalist had written were influenced by the tone of the conversation and their level of trust in the journalist's abilities.

> **Bavesh Kana**: I ask to see the story before it goes to print, but I don't insist, unless I feel like the interview has taken a contentious tone.
>
> **Bruce Rubidge**: I often do ask to see the copy, especially if I don't have confidence in the journalist. Some journalists really don't have a clue what they are doing, and you know from talking to them that they are going to make a mess of it. So, then I ask to see it. And, usually, it is an absolute mess.

Scientists who saw no need to check the journalist's copy were the exception.

> **Anthony Turton**: I have never asked once to edit or to change whatever a journalist has written. I have said that if they want to check some facts with me, they are more than welcome to run it past me.

Some of the more forceful ways by which visible scientists took control of the media agenda included providing only written answers, or bypassing journalists altogether, or even refusing future collaboration unless the media complied with their demands.

> **Tinyiko Maluleke**: One of the reasons that I started to write popularly, was because I wanted to be in control of what I say. Journalists take the control away, and sometimes they just totally misunderstand or misuse what you said.
>
> **Dave Pepler**: I insist on structured interviews where I get to edit the final text. Or, they must send their questions to me and I will send my answers via email. If they are not willing to do it in one of these two ways, I just say sorry and goodbye.

> **Amanda Gouws**: I have had running battles over how my centre page articles are edited when I feel they have changed the meaning of what I said. I would say to them: Listen, if you want to work with me, then it must be done correctly. And if we are constantly going to have problems, then I will no longer work with you. So they know.

A few visible scientists pointed out that, should the media get it wrong, scientists were not powerless to do something about it.

> **Linda-Gail Bekker**: I have managed to weather a handful of bad experiences with the media, including one with *Noseweek*.[69] We had a good conversation and solved the problem. And, really, all I had to invoke was: 'Are you sure you have your facts straight? Because I am pretty sure I have my facts straight, so let's compare facts.'

> **Dave Pepler**: It is up to you to respond if you are quoted incorrectly. Use the media and social media to set the record straight.

Despite an apparent desire to control the story written by journalists, at least in terms of accuracy of the science, visible scientists agreed that journalists had a right to adopt a critical perspective when they wrote about science.

> **Cathi Albertyn**: I don't mind if the journalist takes a critical angle on my work, because I believe in what I do. It should not offend a scientist when that happens. You should be confident enough in your own work to argue your case.

> **Bruce Rubidge**: We must embrace critical questions from the media fully. I don't want anybody to think I have anything to hide, not in my field.

One interviewee referred to the fact that science journalists put too little effort into writing science stories, and often simply re-hashed institutional press releases without doing any further research to write their own stories.

> **Andrew Forbes**: Often journalists copy press releases word for word, or – even worse – write something about what other journalists wrote. They write stories about stories, not about science. And they never even look at the original science article. I have a big problem with that.

Despite a generally good relationship with the media, visible scientists did perceive risks that could result from media interactions, over and above being misunderstood or misquoted. These concerns related to their perceptions that, occasionally, journalists were set on creating sensation or controversy. The differences in the professional cultures of scientists and journalists, as discussed by Nelkin (1995), Claessens (2008) and Peters (2014) were evident in these comments.

> **Cathi Albertyn**: The problem with journalists is … they know how to push you. And, they know how to make you say things that you don't want to say. They have an objective, because they want to sell a story. These are the worst kind of journalist and you have to be extremely disciplined with them.

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[69] *Noseweek* is an investigative monthly magazine in South Africa – see www.noseweek.co.za.

> **Andrew Forbes**: You have to be very careful of what you say to journalists. And, you have to review what they write.

> **Linda Richter**: Journalists often try to turn exciting science into a controversy, instead of just focusing on why it is interesting and relevant.

> **Lee Berger**: Science is not politics, but journalists often try to turn science into politics. They look for a contra-opinion and create a fight where there actually is none.

> **Marcus Byrne**: It worries me that the 'Cor, blimey, shock, horror' stories also grabs the news much more than other stories. We've been around the block a million times on Parktown prawns,[70] but that always generates a lot of response.

The challenges and risks that visible scientists perceived in terms of working with journalists were not unique to South Africa. Earlier studies in other countries show that scientists complain about similar problems, such as inaccuracies (Bucchi & Saracino, 2012; Gonon *et al*., 2012), a lack of expertise (Corley *et al*., 2011), as well as sensationalism and hype (Goodell, 1977; Gregory & Miller, 1998; Weigold, 2001). Further concerns on the part of scientists related to the pressure they experienced from journalists to release information about research in progress.

> **Glenda Gray**: I worry that if we do too much media engagement while we are doing the research, it will be so much more devastating if we fail to find the solutions we are looking for. I'm concerned about this HIV vaccine trial. Everybody is waiting for the results and there is so much pressure on the scientists. If I could have my way, I would have flown under the radar with this one.

> **Tebello Nyokong**: The media wants a product and they want it now. It makes me uncomfortable. I try to explain, 'Look, we are trying to get there, but for now we are not there yet', but that is not what they want to hear.

Notwithstanding discomfort with some of the demands of the media, visible scientists typically displayed an awareness of how the mass media operate and what approaches would have media appeal.

> **Bob Scholes**: When speaking to the media, you need to be much more direct and bold than you would be in a scientific conversation, where you put in all the ifs, buts, maybes and caveats. You need to be willing to go on air and make things simple and accessible, accepting that you will be making some generalisations.

Being aware of the time constraints faced by journalists, most visible scientists emphasised that they made a point of responding to media requests timeously.

> **Amanda Gouws**: I have a reputation that I always say yes to media interviews. Journalists phone me any time and I've done interviews in the middle of the night. This is important, because once you give the media the cold shoulder, you burn those bridges. And, it takes long to gain the confidence of the media, so I cannot afford to burn those bridges.

[70] 'Parktown prawn' is a common name for a species of king cricket endemic to Southern Africa.

> **Himla Soodyall**: I prioritise media requests, because I'm aware of how their deadlines work. I will do my own work after-hours, because I respect the journalist that needs information or an opinion from me right away.

> **Tim Noakes**: My rule number one is, when a journalist phones, answer immediately. You never ignore a journalist. I've followed that rule for 40 years, and I have had very good relationships for most of that time.

Visible scientists also appreciated that something quirky or unusual in science could have significant media appeal. For example, Thackeray's account of the media interest in whether Mrs Ples was male or female and Byrne's reflection on how journalists reported on his work with dung beetles are cases in point.

> **Francis Thackeray**: A few years ago some of my colleagues put out a paper in the *Journal of Human Evolution* with the title: 'Sex at Sterkfontein, Mrs Ples is still an adult female'.[71] We have now done more research and will present a paper that strongly demonstrates that Mrs Ples is indeed male. The title for this paper will be 'The sexual dimorphism and ontogeny of *Australopithecus Africanus*', but unofficially – for the media – we will call it 'More sex at Sterkfontein – the naked truth'.

> **Marcus Byrne**: It is surprising what the media can do with poo. They fiddle with my titles and come up with titles like 'Talking crap' when reporting on my dung beetle research. But, they call the shots and by and large I really enjoy it.

By contrast with these comments from Thackeray and Byrne, Massarani and Peters (2016) find that scientists think that it is inappropriate to use catchy phrases to describe their work in order to please reporters, despite the fact that journalists see this as an important strategy to get public attention. Since the current study focused on visible scientists, it provided further evidence of how visible scientists were more willing to play by the media's rules than other scientists.

Visible scientists were aware that the mass media (including media organisations and journalists as individuals) were under pressure. They took these limitations into account when they judged how the media performed in terms of science reporting, and they expressed concern about the future of science journalism in South Africa.

> **Anthony Turton**: Because of the explosion of the digital world, the media are under severe pressure at the moment and there is very little good-quality investigative journalism.

> **Bob Scholes**: Most of our journalists have very little science background, and they write about science as one of many things they do. You have to understand that. So, occasionally you will be misquoted or they will get the wrong end of the stick. It happens.

> **Linda Richter**: The few good science writers we have are now pulled in every direction to cover absolutely everything.

> **Tebello Nyokong**: Journalists have a difficult job covering science in South Africa. I admire them and try to help them as much as possible.

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[71] Reference for this article: DOI: 10.1016/j.jhevol.2012.01.010

Linda-Gail Bekker: I am worried about science journalists as a group. Before, they used to come to our press conferences in droves. Now, we might get two or three. The excuse is: 'We are all working overtime; nobody may leave the office and we have no money to travel'. I am definitely concerned, because this is not the time to have less science writing.

Lee Berger: Science journalism has changed dramatically in the last 15 years. The historically aware, professional science writer is practically an extinct species.

5.2.4.2. Preferences for different types of media

While visible scientists in the current study were largely positive about media interactions, they differentiated between different types of media. Some expressed a strong preference for specific media outlets, and often a strong dislike for others. This was in line with the observation by Nolte (2012) who notes that experiences and requirements differ vastly between different types of media and that different skills are required and different rules apply when scientists are interviewed for print, radio and television. Several visible scientists in the current study indicated a strong preference for being interviewed on radio.

Glenda Gray: I like radio, but I hate television. I hate the cameras.

Bob Scholes: The first time on TV is always a terrifying experience. I did radio for a long time before I did television. I find radio easy. It is a much more forgiving medium. The interviewers are no less sharp, but much more willing to let you express yourself**.**

Amanda Gouws: I do a lot of radio. You must be able to think on your feet, but I enjoy that. Television is in your face and I find that a very difficult medium.

Dave Pepler: I prefer radio and television. When you are interviewed by a print journalist, something gets lost. The core of the science is still there, but the wonder is lost.

Bavesh Kana: I find radio very effective. With community radio I can reach the people I need to reach. We can have conversations. It allows people who phone in to remain anonymous. It is a really powerful tool in our efforts to de-stigmatise TB.

Mary Scholes: Some of our radio channels are really effective – especially the talk shows on Cape Talk and Radio 702. And then there is Power FM with a huge late-night audience of young, black listeners. They have asked me to come on air around midnight. It is inconvenient, but it is worth it.

Salim Abdool-Karim: Being featured on television evening news – either eTV or SABC – really gets a response. On radio, SAFM is also really effective.

Visible researchers were also aware of the challenges presented by language diversity in the mass media in South Africa. Gouws expressed a strong preference for English media for strategic reasons, while Maluleke indicated that he would like to write for the Afrikaans media.

Amanda Gouws: I can tell you now that if my research results are reported in the Afrikaans media, the government will never take notice of it, because not one of them reads Afrikaans. And I think that is a big problem. That is why I prefer to publicise my results in the English media.

> **Tinyiko Maluleke**: I have never been asked by Afrikaans newspapers to write for them. I write for the *Sunday Independent* and *Mail & Guardian* because they approached me and they seem to appreciate what I write for them. But, I've never been invited by *Radio Sonder Grense*[72] or an Afrikaans newspaper.

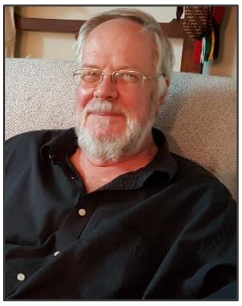
Reminiscent of the findings of the current study, Van der Auweraert (2008) identifies three key barriers in the relationships between scientists and the mass media, namely different news values, different work cultures in terms of style and time scales, and clashes about final control of the copy that appears in print media. Scientists in Van der Auweraert's study were equally concerned about the risk that the media would sensationalise or manipulate their work, or quote them out of context, and they feared that journalists would pressurise them to say things they did not want to say. Despite these fears and negative views, these scientists reported mostly positive experiences regarding their recent media interactions, as was also the case in the current study. Consequently, it seems that visible scientists' fears of what could go wrong during media interactions are generally not strong enough to deter them from interacting with the mass media.

5.2.4.3. Attitudes towards mainstream media: summary

Visible scientists in South Africa participating in this research were overwhelmingly positive about their media interactions, and valued the strategic potential of productive partnerships with journalists. In general, visible scientists understood the media and were prepared to adapt to the needs of the media. Media knowledge and experience, good relationships with individual journalists and a willingness to adapt to media needs, allowed visible scientists to use the media strategically to achieve their communication objectives. Lingering concerns related to ill-prepared journalists, inaccuracies and hype, and unmet expectations about controlling the final version of print media stories. Interviewees were concerned about changes in the mass media ecosystem and the potential future influences on public communication of science.

5.2.5. The influence of attitudes towards social media

I have learnt more about science from Twitter than I have ever learnt before. It is just astonishing how many papers are shared and discussed via Twitter. Almost everything I know about how the field of nutrition advanced in the last five years, I got from Twitter. *(Tim Noakes)*



Social media allows new discoveries to spread around the world in no time, reaching new, previously uninformed, audiences. *(Francis Thackeray)*

As is the case with mainstream media, scientists' attitudes to social media were expected to influence their public science communication behaviour.

[72] National Afrikaans-language radio station – see www.rsg.co.za

5.2.5.1. Attitudes towards social media

My question to participating scientists in South Africa about their views of social media as a science communication tool elicited strong reactions, with many scientists fundamentally opposed to social media and a few enthusiastically in favour of it. Based on their responses, I have classified visible scientists into three categories: 'avoiders', 'experimenters' and 'enthusiasts'.

Half of the interviewees (n = 15) have never used Facebook or Twitter and did not intend to use it in future as a way to communicate their research. They were the 'avoiders'. A third of the group (n = 10) were somewhat undecided about social media. They were typically on a learning curve, while some were using one platform (for example Facebook), while avoiding others (such as Twitter). These 'experimenters' were typically interested to acquire more social media skills. Only five interviewees – the 'enthusiasts' – have embraced social media and were strongly in favour of using it as a science communication tool.

The three tables below list the responses of the individual scientists when I asked them how they felt about using social media for public science communicating. In Table 5.1, I captured the views of the avoiders. In Table 5.2, I reflected the answers of the experimenters. In Table 5.3, I recorded how the enthusiasts responded.

Table 5.1: How 'avoiders' feel about social media

Salim Abdool-Karim	I don't do Facebook and Twitter and things like that.
Mary Scholes	I don't do the social stuff. I don't do Twitter and I don't do Facebook.
Marcus Byrne	I don't really go there.
Kelly Chibale	I don't like those things.
Jill Farrant	I don't do the social media stuff.
Himla Soodyall	I have stayed out of it.
Glenda Gray	I am not going to do Twitter.
Don Cowan	I don't blog and I don't do Twitter.
Cherryl Walker	I don't engage with social media.
Cathi Albertyn	I don't like it and I'm completely useless at it. Twitter, I think, is just rubbish.
Bruce Rubidge	I don't use it because ... I just don't.
Bob Scholes	I don't do social media. Partly, it is that I am just an old fart.
Pumla Gobodo-Madikizela	Oh, my goodness, that is something else!
Andrew Forbes	I'm not a fan of social media. To be honest, I hate it.
Amanda Gouws	No, I don't go into that.

Table 5.2: How 'experimenters' feel about social media

Bavesh Kana	I have never posted anything, but I'm learning.
Tebello Nyokong	I think we should go there, but I can't use any of them.
Sheryl Hendriks	Social media is changing science communication completely. We have big dreams of how we will use it in future.
Linda-Gail Bekker	I am learning. We are trying to get up to speed.
Linda Richter	I got into Twitter by accident. But, I'm still an unsophisticated tweeter. I need more training.
Hamsa Venkatakrishnan	I very rarely do it. I like reading stuff, but rarely post anything.
Francis Thackeray:	There is a lot to be said for social media.
Dave Pepler	I have a fairly powerful Facebook page. But I don't tweet.
Anusuya Chinsamy-Turan	Once you've experienced how far and wide a good, visual Facebook post can be shared, you start to appreciate the power of social media.
Anthony Turton	I've dabbled a bit with Facebook and Twitter, but I have not really embraced it.

Table 5.3: How 'enthusiasts' feel about social media

Tolullah Oni	I love Twitter. That is my thing.
Tinyiko Maluleke	Social media is powerful.
Tim Noakes	If you're not active on Twitter, you're behind the game.
Nox Makunga	I enjoy sharing my research on social media, especially Twitter.
Lee Berger	If you don't want to communicate with a very important, entire generation of human beings on this planet, then don't use social media.

Earlier studies by Brossard (2013), Brossard and Scheufele (2013) and Liang *et al*. (2014) validate Berger's perception that online audiences are becoming increasingly relevant for public science communication. However, the relatively low proportion of visible scientists that have embraced social media as a preferred communication tool was in line with a recent study showing low adoption rates amongst scientists (Collins *et al*., 2016).

The five social media enthusiasts in the study all mentioned Twitter as a tool during the course of the interview. In Table 5.4, I provide an overview of when they joined Twitter, how many followers they have and how many tweets they have sent to date. Interestingly, Tim Noakes (who emerged as the second most visible scientist in the country) had the highest number of Twitter followers, with the most visible scientist (Lee Berger) in the third place.

Table 5.4: Twitter profile of the social media enthusiasts

Interviewee	Twitter handle	Twitter start date	Followers by 4 October 2017	Tweets by 4 October 2017
Tim Noakes	@ProfTimNoakes	April 2012	94 098	37 606
Tinyiko Maluleke	@ProfTinyiko	September 2012	17 792	7 354
Lee Berger	@LeeRBerger	April 2010	8 961	5 641
Nox Makunga	@noxthelion	May 2012	1 709	7 524
Tolullah Oni	@DrTolullah	March 2014	1 012	3 435

5.2.5.2. Reasons why 'enthusiasts' like social media

For me, social media has definitely connected me to top academics that I would not otherwise have access to, and this has translated into tangible academic benefits.
(Nox Makunga)

Scientists who support the use of social media (either doing it themselves or working with colleagues who use social media tools on their behalf) describe a range of perceived benefits that they have experienced from using these communication tools, mostly related to its immediacy, reach and interactive nature. These perceived benefits were similar to the advantages of social media that Casini and Neresini (2012) describe.

> **Bavesh Kana**: When we communicate about TB, we need the messages to go out far and wide – and that is why social media is so useful to us.
>
> **Anusuya Chinsamy-Turan**: Once you experience how far and wide a good, visual Facebook post can be shared, you start to appreciate the power of social media.
>
> **Dave Pepler**: The power of Facebook is in simple engagement. Once people cotton on that there is something alive behind this flat screen, it becomes very powerful.
>
> **Tebello Nyokong**: Social media is the way to go; that is where young people are.
>
> **Lee Berger**: Scientists are now much more actively communicating their science – partly because the mediators are disappearing, and partly because we can – thanks to social media.

In line with the comment by Berger, scholars like Peters *et al*. (2014) and Dudo (2015) agree that social media allow scientists to become pro-active in terms of sharing their science, and remove the need to attract media interest in order to become publicly visible. Several interviewees implied that they would like to use social media more effectively than they were doing at the time, and that they would appreciate some help in mastering these communication tools.

> **Don Cowan**: Occasionally I feel guilty that I am not using it more effectively myself.
>
> **Tebello Nyokong**: I think we should go there – we have no choice. But, I can't use any of these tools – I need help.
>
> **Anusuya Chinsamy-Turan**: Just the other day I said to my colleague: 'One of these days I am coming to see you because you need to help me get me a Twitter account and explain to me how it works, because I don't actually know'.

Some of the scientists who were not keen to use Facebook or Twitter, mentioned that they did support other social media channels, and YouTube in particular.

> **Don Cowan**: YouTube has a huge benefit. It stays online and can be viewed and tracked for years.
>
> **Mary Scholes**: I have collaborated on doing YouTube interviews on a number of occasions. The number of hits and emails you get from that is really amazing.

5.2.5.3. Reasons why 'avoiders' do not like social media

The social media avoiders in the current study described social media negatively, using adjectives such as 'risky', 'frightening', 'constraining', 'problematic', 'vacuous', 'damaging', 'puerile', 'dangerous', 'annoying', 'frivolous' and 'offensive'. They cited a range of reasons for their dislike of social media, including that they perceived it as a high-risk activity. Their concerns were also due to a perceived lack of context, a lack of privacy, and a lack of credibility that they associated with these platforms.

> **Glenda Gray**: Twitter can get you into big trouble.
>
> **Amanda Gouws**: There is no context.
>
> **Cathi Albertyn**: The problem with Twitter is that people produce and reproduce untruths or half-truths all of the time. Also, people get angry very quickly and they don't argue well.
>
> **Kelly Chibale**: I don't want everybody out there to know everything about me.
>
> **Dave Pepler**: The offering is too broad. How do you comb through it?
>
> **Bob Scholes**: I find the move into the Twittersphere quite disturbing. What is the depth in that? How do you tell rubbish from truth in that kind of format? That worries me.

Several science communication scholars have written about the downside of social media, including the perception that it is a high-risk and potentially damaging activity that could detract from the credibility of science (Mandavilli, 2011; Weingart, 2012; Dudo, 2015). As mentioned by Albertyn, social science scholars have expressed concern about the credibility of online information and the inability of non-expert audiences to distinguish between credible and dubious content (Nisbet & Scheufele, 2009; Scheufele, 2013; Yeo *et al*., 2015; Weingart & Guenther, 2016).

Several interviewees mentioned the perceived time demands of social media as the reason why they avoided it or felt the need to manage it carefully.

> **Himla Soodyall**: I have stayed out of social media because it will take too much time. I don't have the capacity to manage it.
>
> **Don Cowan**: You get locked in to it and it becomes a burden eventually.
>
> **Bruce Rubidge**: I have between 150 and 200 emails a day to answer. That is enough for me. I really don't have time to tweet and to Facebook and all of that stuff.
>
> **Dave Pepler**: Facebook is a hungry animal that wants to be fed every day.

Interestingly, Noakes (with 94 098 followers on Twitter by 4 October 2017, see Table 5.4), said that he spent two hours every day on Twitter.

The responses from some of the avoiders and experimenters indicated that they perceived social media as a platform for younger people and that this age barrier prevented them from being more involved.

Don Cowan: Because of my age and focus of interest, I just have not exploited it as well as others.

Bavesh Kana: I may not look old, but I am old. I was born in 1975. I use my phone to phone.

Bob Scholes: I'm just an old fart, so it is not a natural medium for me.

Mary Scholes: But then I am just old-fashioned and judgemental so that is why I don't do it.

Bruce Rubidge: My problem is simple – I am a 'plasie'[73] and I have not adapted to technology.

Glenda Gray: Maybe that belongs to a younger generation of scientists, and maybe that is a nice place for younger people to engage.

However, some of the interviewees indicated that they were aware of the potential influence of social media and therefore made sure that colleagues engaged on their behalf.

Mary Scholes: If a scientific finding needs to get out there I can convince my media officers at the university to get it out there. They have a Twitter feed. But, I am not going to do it.

Sheryl Hendriks: I am not an avid social media person. But, that is certainly part of our team. So there are people who are more willing to do it.

Bavesh Kana: I have somebody in the lab who manages our Facebook page and our Twitter account.

Salim Abdool-Karim: The world is moving forward and old ways of communicating are changing. We have to find ways to keep up with that, even if I can't do it myself.

Anusuya Chinsamy-Turan: My younger colleague, Roisin Kelly, is in charge of the Twitter feed for the department.

The reasons why visible scientists in the current study were avoiding social media (or were hesitant about using it) were similar to the barriers that emerged in earlier studies, namely time pressures and a lack of skills (Regenberg, 2010; Bik & Goldstein, 2013), and the perception that social media are not a suitable platform for communicating science (Esposito, 2013; Collins *et al*., 2016). However, half of all the visible scientists interviewed in my study were either already using social media intensively for public science engagement (enthusiasts; n = 5), or interested to become more skilled so that they could use it in future (experimenters; n = 10). This echoed scholarly views and findings that scientists are becoming increasingly sophisticated in terms of social media use (Allgaier *et al*., 2013b; Brossard, 2013), and that they are particularly aware of the potential benefits offered by Twitter (Priem & Costello, 2010; Darling *et al*., 2013; Bombaci *et al*., 2016).

5.2.5.4. Attitudes to social media: summary

Scientists generally had strong opinions in favour of or against social media as a science communication platform. Most were currently (i.e. at the time of this research) not using it, or were using it in a limited way. Some of the interviewees perceived barriers and risks that deterred them

[73] 'Plasie' – a colloquial South African term for someone who grew up on a farm.

from considering these platforms for current or future use, while others indicated that they were planning to use social media tools in future. There was a keen interest in social media training among about one third of the group. The fact that most visible scientists in the current study were not yet actively using social media, and only five of the group of 30 saw Twitter as an important science communication tool, meant that social media use was not a prerequisite for achieving public visibility. However, the fact that the two most visible scientists identified in the current study (Berger and Noakes) were among the five social media enthusiasts, suggested that social media might have the ability to elevate visibility in the public sphere.

5.2.6. The influence of perception of a moral duty to communicate

Communicating with the public is a right, rather than an obligation. *(Cathi Albertyn)*

I am a beneficiary of South African society. I value that. It is only ethical and moral to give back to society. It is the right thing to do. *(Mary Scholes)*

Scientists' perceptions of whether or not they have a duty (or obligation) to communicate with public audiences have been shown to influence their interest and willingness to become involved in these activities. In this section, I present findings from the current study about whether visible scientists in South Africa perceive a duty to communicate with public audiences.

5.2.6.1. Visible scientists' perception of a duty to communicate with the public

It is typical for scientists to disagree about whether public science communication is a duty that could or should be demanded of each scientist (Van der Auweraert, 2008). Most of the visible scientists in the current study agreed with the notion that scientists had a collective duty to communicate with audiences outside the academic world, while a third of the group (n = 10) felt that this duty could be demanded of all scientists.

> **Lee Berger**: Every scientist owes an obligation to society to communicate. I don't believe you should have a choice in it.
>
> **Dave Pepler**: Scientists do not realise that they have a huge obligation to humanity. They have an obligation to life. Life owes them nothing, but they owe a hell of a lot to life. If they are having a good life, not teaching themselves to death and travelling all over the globe for conferences, then they have an obligation to give back.

Others perceived this duty on a personal/individual level, and did not indicate that it necessarily applied to fellow scientists.

> **Bob Scholes**: I have always believed that communication with the public is an obligation of scientists. It is not debatable; it is part of my job. We can have a debate about whether we do it well or badly, and whether we do it for good or for bad. But, for me, it has always been a given.
>
> **Himla Soodyall**: For me, public communication comes with the territory of being an academic.

> **Pumla Gobodo-Madikizela**: I feel a sense of responsibility to tell the story of my research – a strong feeling that this has to be conveyed.

The majority view of the participating scientists was that they perceived a duty to engage with the public. This was in line with findings from studies in many other countries, including the United States (Mathews *et al*., 2005; Corley *et al*., 2011; Pew Research Center, 2015b), the United Kingdom (MORI, 2001; The Royal Society, 2006; Miller & Fahy, 2010), Denmark (Wien, 2014), the Netherlands (Dijkstra *et al*., 2015) and Brazil (Massarani & Peters, 2016:7). A study in Sweden (Vetenskap & Allmänhet, 2003) showed that eight out of ten scientists (a higher percentage than in South Africa) thought that all researchers should be obliged to communicate with the public.

In line with findings from Mathews *et al*. (2005) and Dudo (2013), scientists' perceptions of a duty to communicate with external audiences were frequently motivated by the fact that they worked with public funding which translated, in their view, into a duty to be responsive to society.

> **Marcus Byrne**: I see myself primarily as a civil servant. You, as a taxpayer, are paying me. If you ask me a question I have to do my best to answer you – whether about dung beetles or water hyacinths. It is my duty to respond.

> **Bruce Rubidge**: If you are dealing with public money, you should give back to the public. They want to know what their money is being spent on. It is your duty, and if you neglect this duty, you are doing the country a disservice.

> **Glenda Gray**: Scientists at the MRC [Medical Research Council] are using taxpayers' money to do research. The public deserves to know what is happening with their money and see the results. We, as public servants, should be discussing it with the public.

> **Pumla Gobodo-Madikizela**: How can we justify our existence if we don't engage with society visibly and clearly, and respond to the complex issues in our society?

Visible scientists were keenly aware of public expectations and concerns around how public money was used in South Africa. Several of them felt that active participation in public science communication could help to reassure the public about public taxes spent on science.

> **Jill Farrant**: Communicating with the public may help to illustrate that tax payers' money is well spent, especially now that we have public protests about the way the government uses public money.

> **Kelly Chibale**: When the government says, let us put some money aside for research, people need to understand how this money will be used. The individual scientist plays a very, very important role. Scientists often don't realise that they have a huge responsibility here.

However, visible scientists' motivations for public engagement went beyond efforts to justify public funding, extending to people's democratic rights, a desire to contribute to education, obligations towards research participants and a desire to engage with affected groups in society.

> **Bob Scholes**: We all basically work off the public purse. Very few of us are privately supported. But, also it is in the public interest. It goes beyond the money. I also speak to

American publics and publics in other African countries. People have the right to know certain stuff.

Don Cowan: There is a growing perception that we really do owe it to the public to engage with them, since we are using public money for what we do. So, we should at least inform the public what we do in a way that they can understand. Scientists should contribute to broad public education.

Cherryl Walker: I am funded by the NRF, so there is a sense of responsibility to engage with external audiences. But there is also a kind of ownership of some ideas that you actually want out there. You want engagement.

5.2.6.2. Perception of a moral obligation to communicate

The literature shows that some scientists perceive a particularly strong moral obligation when it comes to sharing their work with society (Torres-Albero *et al.*, 2011; Grand *et al.*, 2016; Molinatti & Simonneau, 2015). Manzini (2003) makes a strong morally based argument for scientists to share their work in a multi-cultural, diverse and unequal society such as South Africa. Some of the visible scientists in the current study were similarly compelled by moral and ethical convictions to engage with public audiences.

Kelly Chibale: It is my responsibility – as the custodian of new knowledge – to share that. For me, it is just like any gift. God gives us gifts and talents – not to keep to ourselves, but to share with others.

Nox Makunga: People need to see what is happening in science – how we understand our world and improve lives. These things are directly relevant to the public. They have a right to know.

Anthony Turton: Science must have a moral conscience; science must serve society.

In the case of health research and clinical trials, researchers perceived a need to give feedback to the members of the public who were involved in the research. Correspondingly, Burchell *et al*. (2009) found that scientists are motivated to engage with communities by a desire to give something back to the patients who participated in their research.

Linda-Gail Bekker: I work directly with communities where people step forward to get involved in my research. So, I feel a huge responsibility to communicate with them during and after the research. I teach all my staff and students that it is very important that the participants are always informed on the information we have discovered.

Regarding the question of whether public communication should be a requirement of all scientists, most interviewees were reluctant to agree. For example, Abdool-Karim, Maluleke and Rubidge agreed that they felt obliged to participate in public engagement themselves, but they thought that other scientists should have a choice in this matter.

Salim Abdool-Karim: Why would you want to force scientists who do not want to communicate, to do it? Some people just don't like it – they prefer to work quietly in the lab.

Tinyiko Maluleke: I wouldn't want to prescribe it for someone in the natural sciences. I would encourage them, but I wouldn't force them.

Bruce Rubidge: Everybody is different, and some are better at public engagement than others. If it comes naturally, take it forward. There is no use forcing it.

Visible scientists were mindful of the fact that not all scientists were necessarily skilled communicators, and suggested this as one of the reasons why public communication could not be an obligation placed on researchers across the board.

Cathi Albertyn: I don't think everyone communicates necessarily very well. Public communication should be encouraged and enabled, but never regarded as an obligation.

Tebello Nyokong: I am reluctant to demand public communication of all scientists, because there are some people who are not so inclined.

Bavesh Kana: This is not for all scientists. If they really don't want to do it, rather leave them alone.

Interviewees were cognisant of the difficulties some scientists would experience if they were forced to participate in public communication activities.

Marcus Byrne: For some people, it would just kill them. It is not fair to put people through the wringer just because we think they should be out there standing on a podium.

Jill Farrant: Scientists should have a choice. Not all of them have a topic that is going to catch the public's imagination. And there is nothing worse than giving a talk and no-one really likes it.

Kelly Chibale: It is not fair to expect every scientist to communicate what they do with the public. Not every discipline lends itself to public communication, and it also depends very much on the audience being targeted.

Tim Noakes: The reason that I am successful is that I am a generalist. I stand in a broad field of human endeavour. It is ridiculous to demand of a scientist who works on a single cell or a single protein to go and speak to the general public.

In support of the view that it would not be ideal to make public communication a compulsory requirement for all scientists, it was pointed out that forcing scientists to communicate in public could be counter-productive.

Don Cowan: Insisting that every academic has some sort of public persona might be a very bad idea.

Himla Soodyall: You have to really be passionate about science communication if you are going to do it well. Forcing people to do something does not necessarily translate to a productive outcome.

Anusuya Chinsamy-Turan: If you present a mass of information that is not engaging, you may alienate people instead of drawing them in. That is what will happen if you force scientists to communicate with the public. If they don't have a passion for public engagement, they will kill people's interest in science.

The idea that public communication of science should be left to scientists who do it well, also surfaced in the study by Van der Auweraert (2008). In the current study, interviewees furthermore suggested that, instead of expecting all individual scientists to participate in public science communication, scientists who preferred to stay out of the public sphere could work with other communicators or team members in order to contribute to public science communication.

> **Linda Richter**: Instead of forcing every individual scientist to communicate, I would find a person in a research team who can represent the research.

> **Marcus Byrne**: Making it a requirement for a scientist to do public engagement is probably not a good idea. But, at the very least, they can help to identify good stories for the press.

Instead of demanding that all researchers communicate, interviewees were generally in favour of a supportive approach that would encourage, rather than prescribe, public communication.

> **Tolullah Oni**: It is absolutely important that scientists should engage, but we don't need a 'make me' approach. We'll get further with diplomatic encouragement and support.

> **Tinyiko Maluleke**: I wouldn't want to prescribe it for someone in the natural sciences. I would encourage them, but I wouldn't prescribe it.

Administrative burden and academic freedom were mentioned as two further reasons why interviewees generally did not support the idea to demand public communication from all scientists.

> **Cherryl Walker**: Academics are under enormous pressure to perform. I would hate to add another audit culture set of boxes that you have to tick and show performance on.

> **Amanda Gouws**: Well, you know, there is the matter of academic freedom. And academic freedom is the choice of being able to decide what you want to research, how you want to do it and surely then, how you want to communicate it.

The comment by Gouws corresponded with the findings from a UK study (Abreu *et al*., 2009) that, given the fundamental importance of academic freedom, not all academics needed to engage with external audiences in order to fulfil their academic duties properly. Albertyn was of the opinion that public communication of science was a right, rather than an obligation (see the introductory quote at the beginning of this chapter). Interestingly, none of the interviewees made any reference to the need to get approval before going public with their views, or any instance of their public communication being controlled by the institutions where they were working at the time of this research, as was found by Searle (2011) in an Australian study.

5.2.6.3. Perception of a moral duty: summary

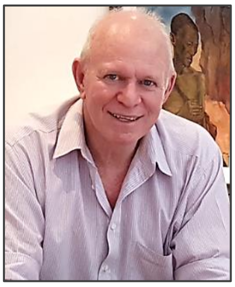
The scientists interviewed for the current study generally agreed that scientists should communicate with the public, but most did not agree that this should be demanded of all scientists. For many scientists, the idea that they owe something to society stemmed from the fact that their work was publicly funded. This motivation was especially relevant in South Africa where scientists were aware of public concerns about squandering of public funds. Consequently, they felt that it was important to demonstrate to the taxpayer that money allocated to research was well spent.

Furthermore, visible scientists perceived a moral duty to serve society by contributing to education and the democratisation of science, especially given the societal inequalities that are prevalent in South Africa. Visible scientists' reluctance to make public communication an obligatory activity for all scientists was based on their perceptions that many scientists would not be good at public communication and may, in fact, do more harm than good should they be forced into these activities. Furthermore, they felt strongly about the need to safeguard academic freedom and avoid additional demands on academics.

5.2.7. The influence of scientists' perceptions of self-efficacy

It is difficult enough to explain your work to scientists in other disciplines, and even harder to generate curiosity and excitement in the public.
(Himla Soodyall)

Confidence comes from knowing your stuff.
(Anthony Turton)



In this context, 'self-efficacy' refers to scientists' perceptions of their own skills in terms of communicating science to public audiences.

5.2.7.1. Visible scientists value public communication skills

My interview data illustrated that visible scientists valued these public communication competencies and thought that those who mastered these skills had an advantage over other scientists.

> **Kelly Chibale**: The one thing I learnt while working in the US is that even the most brilliant scientists, including some Nobel Prize winners, think constantly about how to communicate what they do. They do media interviews all the time, because they know how important it is to have journalists who champion your cause. That made me realise how important it is to communicate to the public, and to acquire the specialised skills required to do so.
>
> **Bavesh Kana**: Science is a social sport. So, whether you are having a beer at the pub, or whether you are at a conference where funders are roaming, you have to form connections and engage.
>
> **Tolullah Oni**: We like to remove ourselves from the equation, but often the messenger is as important as the message. How you say it may matter even more than what you say or who is saying it.

Oni's comment about the importance of the communication style resonated well with observations and advice from science communication practitioners such as Dean (2009) and Olson (2009).

5.2.7.2. Visible scientists' perceptions of own and fellow scientists' communication skills

Visible scientists were mostly confident about their own communication skills and abilities to convey their research to lay audiences. Some saw this as a natural talent or even God-given gift.

Linda-Gail Bekker: Being able to communicate is a gift. I'm lucky that I have that gift and I like to use it.

Jill Farrant: I believe I have a sort of innate ability to be passionate about my work and to express it well. It is a gift that God gave me.

Himla Soodyall: I have the capacity to make science entertaining. I am able to communicate in a way that people can understand what I'm saying. I can give a talk without any visual aids and still hold the attention of my audience.

Amongst the group of visible scientists, only two individuals (Richter and Gray) perceived themselves as not being 'natural' communicators (although they acknowledged the importance of doing it).

Linda Richter: It does not come naturally to me. I'm not like my friend Lee Berger, who is a natural communicator.

Glenda Gray: I will engage, even though it is definitely out of my comfort zone. I would prefer to stay under the radar.

However, on the topic of using social media, several visible scientists admitted that a lack of skills inhibited them from using these communication tools.

Cathi Albertyn: I am completely useless at social media and I avoid it.

Anusuya Chinsamy-Turan: I wanted to use Twitter, but I didn't know how, to be quite honest. Now that I've signed up, I'm loving it!

Glenda Gray: I would not use social media, I would probably mess it up.

When commenting on the communication skills of peers and colleagues, visible scientists were generally negative about the level of public communication skills that they perceived in others, which reflected the widely held view that scientists were generally not good communicators (Olson, 2009; Radford, 2011).

Anusuya Chinsamy-Turan: Many scientists have difficulty in writing press releases and popular materials.

Linda-Gail Bekker: We are not good at public communication. We are definitely not brilliant at it. It is a skills set that is not naturally present in research teams. We could improve vastly.

Himla Soodyall: When communicating science to the public you kind of have to work that situation. And that does take skill. So, not every scientist can do it.

Francis Thackeray: Yes, there are scientists who communicate well, but I can think of some who really struggle.

Sheryl Hendriks: We have some people on our team that I would never put in front of the media.

Bob Scholes: Some scientists are clearly better at this than others.

Tebello Nyokong: The problem with us scientists is that we want to talk about our work, and we want to engage the media. But, we don't know how the media works, so we feel too embarrassed to approach them.

Mary Scholes: Scientists are particularly bad at sharing information. I saw it again in a meeting earlier today. Each talk was supposed to last only 15 minutes so that we would have time for discussion. But every single one of them seemed to think that they would only be credible if they filled up all the allocated time. So, we had no discussion the whole day. Scientists have to learn when to stop. They need to understand that it is not necessary to tell people everything they know.

Tinyiko Maluleke: I believe there are brilliant scientists who will never be able to disseminate their findings publicly, simply it is not in their talent to do so.

Accordingly, Van der Auweraert (2008:143) reports that Belgian scientists did not doubt their own science communication competencies, but were critical of the communication skills of their peers, saying that most of them "can't communicate clearly", "write illegibly" and "communicate chaotically". Furthermore, they thought that their colleagues would be unable to teach communication skills to their students and younger colleagues.

5.2.7.3. Ways by which scientists acquire public science communication skills

Three potential pathways towards improved communication efficacy emerged from the interview data, namely learn by observing others, learn by own experience, and acquire skills through training. For example, Chibale thought of public communication skills as an inborn talent, but acknowledged that he acquired communication proficiency over time, while Forbes was of the opinion that no one was born a communicator, and that communication skills had to be taught.

Kelly Chibale: Some people are born with natural charismatic skills, and some people can develop those skills. I was not born with it. I became skilled as opportunities came along.

Andrew Forbes: Communication skills must be taught – you are not born with them.

While several scientists referred to Berger as an example of a naturally talented communicator, Berger himself did not agree with this view. He emphasised that his communication ability resulted from years of active involvement and practice.

Lee Berger: People say to me, 'Oh, you are a natural.' That is not true! I started learning public speaking as a child. I did debate. I ran for offices in social organisations when I was growing up in a rural community. I was constantly practising the art of communication. I practised writing for different types of media from early on in my career. I practised and practised. It was not easy at first. I think the worst thing – the most damning thing you can do – is to tell a scientist that there are natural communicators and unnatural communicators.

Similarly, Scholes traced the roots of his current communication skills back to a learning opportunity during his early childhood, while Maluleke credited his teacher training for giving him confidence in public speaking, and Turton acknowledged some early-career media training.

> **Bob Scholes**: My communication confidence goes back to an incident when I was 10 years old. My brother had a learning difficulty and my parents signed him up for a year's worth of speech therapy. He died early in the year and the therapy had been paid for. I did not need speech therapy, but my parents sent me to the speech therapy lessons for the rest of year. That therapist taught me habits of speech which I still have. Because of that training, I was never afraid to stand up and speak.

> **Tebello Nyokong**: As a young university student, I was trained to be a teacher – things like how to stand, how to project your voice, how to look at the class, and so forth. That training helped me enormously in public speaking later on.

> **Anthony Turton**: The only communication training I ever had was a media training course that the CSIR [Council for Scientific and Industrial Research] sent me on. I was taught how to speak to a camera. I'm still very grateful for that.

While Goodell (1975) points out that some scientists have an inborn ability to communicate well, along with a natural talent for popularising their work, the science communication literature generally agrees that communication skills can be taught and that scientists become more confident about their own communication abilities over time (e.g. Ruth *et al*., 2005; Metcalfe & Gascoigne 2009; Besley & Tanner, 2011; Crone *et al*., 2011; Dudo, 2013; Ecklund *et al*., 2012; Dijkstra *et al*., 2015; France *et al*., 2015; TNS-BMRB, 2015). Likewise, most interviewees in the current study agreed that their communication skills, and therefore their public visibility, were nurtured over many years of hands-on involvement. And, as pointed out by Nyokong, learning how to communicate was also about learning from mistakes and about what does not work.

> **Tebello Nyokong**: You have to have disasters. You have to get up and give a terrible lecture, and then realise 'That was awful, I never want to do it again'. And you must always want to improve what you do.

> **Kelly Chibale**: The first time I went to a television studio I didn't know what to expect. But, as you do more, you get better at it. You just have to keep an open mind and be prepared to start from somewhere.

"I grew up on David Attenborough and Jacques Cousteau on television," Marcus Byrne told me when I asked him about the origins of his interest in public science communication. Several more scientists explained how they were inspired by, and learned from, big-name science popularisers.

> **Tim Noakes**: We should look at the best communicators in the world and learn from them. David Attenborough is probably the best presenter of science that the world has ever known. No one can touch him. That should be your goal – to be as good as the very best. And, Attenborough did not get there overnight. He's been working at it for 70 or more years. So, being a good communicator takes practice. It is absolutely about practice.

> **Andrew Forbes**: I read a lot about Richard Feynman – he is sort of my hero. He was a brilliant physicist, but also a brilliant communicator. If you read his books, you will find that he has wonderful ways of explaining things clearly and simply. It may look as if he writes these things off the cuff, but in fact he spent hours and hours crafting each explanation. That inspires me. I cannot talk off the cuff, but – with effort – I can make things enjoyable for the public.

Despite acknowledging the value of their own involvement and taking cues from successful communicators, the majority of visible scientists felt quite strongly that students and young scientists should be trained in public communication, and several emphasised that this training should start at undergraduate level. The ability of training to refine and expand scientists' communication competencies is widely acknowledged by science communication scholars (Miller & Fahy, 2010; Horst, 2013), and many agree that this training should start even before science students get their first degree (Leshner, 2007; Brownell *et al.*, 2013; Karikari *et al.*, 2016; Tonya, Train & Miyamoto, 2017).

> **Kelly Chibale**: The sooner and earlier we start teaching communication skills to science students, the better. It must start from undergraduate level.
>
> **Bavesh Kana**: We badly need a module on public engagement in undergraduate science courses. That is where we must sow the communication seeds so that it becomes part of the value system of science.
>
> **Francis Thackeray**: We need to spend at least a few days teaching students how to communicate scientific discoveries. This should definitely feature in university courses, even at undergraduate level.
>
> **Lee Berger**: We are not teaching our young scientists to communicate. We need this, particularly at undergraduate and early postgraduate stages, but carrying through to research careers. Communication training should never stop. I still need help and support from my university to communicate more effectively.
>
> **Marcus Byrne**: I have never had any training in media or presentation skills, but I wish I had. Like with science, feedback and professional advice can make all the difference.
>
> **Andrew Forbes**: In all the organisations where I have worked, they never thought it necessary to teach scientists to interact with the media or how to write a good news story. I have learned by experience, but I think we can become infinitely better if we just recognise that those skills are needed and that uptake can be vastly accelerated with a few training courses.

While acknowledging that training could make a difference in communication confidence and ability, Scholes pointed out, however, that training would not make a 'brilliant' communicator out of every scientist, implying once again that an element of natural talent was also required in order to excel at public science engagement.

> **Bob Scholes:** Even with training, some will never be brilliant. But anyone can become better than they currently are.

On the topic of offering communication training to researchers, only Venkatakrishnan was concerned that academics might not have the time or inclination for this kind of skills development and subsequent involvement in science communication, despite the fact that she was active in media engagement herself.

> **Hamsa Venkatakrishnan**: The academic environment is hard enough as it is. If we now tell academics that they have to learn how the mass media operates, some may have a coronary along the way. I am not sure that there is space in the academy – which is getting more and

> more intensive – to add this additional layer of work. And, it is not something every academic wants to do or necessarily needs to do.

Given their belief in the value of science communication training and experience, many visible scientists pro-actively involved their own students in these activities. They provided training and hands-on experience for their students across a range of skills, but mostly focused on popular presentations and writing skills.

> **Lee Berger**: My students have to present 10-minute talks about their work three to four times every year. I do that because I know – when they leave here with a PhD – they are going to be in the real world where they have to be able to communicate in a variety of circumstances across a broad spectrum of audiences.
>
> **Bob Scholes**: I coach my students in presentation skills. They have to present to me and I give them feedback and tips to improve. It is a big part of their training.
>
> **Jill Farrant**: I don't just teach my students how to do research and interpret their data. I teach them how to write about it too and how to make it meaningful for the public.
>
> **Linda Richter**: Students mostly don't know how to explain what they are working on clearly and succinctly. That's why I tell them, 'When you start a new project, talk about it as much as possible – tell your mother, your friends, your neighbours – anybody that will listen'. This helps them to straighten out their own thoughts and ideas about their research, and they get better at expressing themselves. Soon, we will have a FameLab[74] event to give them a platform for presenting their work in plain language.
>
> **Nox Makunga**: We make our students write popular articles about their research.
>
> **Sheryl Hendriks**: We help our students to develop clear messages about their research. It is often difficult for them to go from broad waffling to the essence of what they want to convey. Then, we let them practice doing elevator pitches. We simulate the situation with a ping as the door opens and a timer running. Then also practice tweeting the main points. When they get feedback – as happened recently when Grain SA challenged one of their tweets – they learn that this is a public domain. They enjoy that and they develop confidence.
>
> **Bavesh Kana**: All my students have to give me a two-minute sound bite as if they are on radio – explaining in two minutes what they do. In the real world, two minutes is all you're going to get. They also practice the situation when they meet a potential funder or employer in a lift and they have to explain what they do really briefly. And, I have a rule – no text on any PowerPoint slides when they present their research talks.
>
> **Anusuya Chinsamy-Turan**: I try to get my postgraduate students to write a popular-level press release every time they write a journal article. It is part of their training and it is part of the experience. It works really well.
>
> **Tebello Nyokong**: We get many visitors here and I let the students talk to them. This is an excellent way for them to practice presenting their research in a way that other people can understand, and to gain confidence in talking about their science.

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[74] FameLab is a popular competition designed to help young scientists engage and entertain public audiences by breaking down science, technology and engineering concepts into three minute presentations – see famelab.org.

5.2.7.4. The skill set required for effective public science communication

I asked the visible scientists in the current study for their views on the type of skills required to be effective science communicators in the public sphere. As illustrated in Figure 5.3, interviewees mentioned five types of skills, with storytelling emerging as the aptitude mentioned by most of them. The other skills were popular writing, presentation skills, public speaking and media skills (doing media interviews). Only three scientists mentioned social media skills. Interviewees described the different skills types as follows.

- Storytelling: sharing personal experiences; talking about your science in a narrative style.
- Popular writing: writing popular books, articles and press releases.
- Presentation skills: presenting focused and compelling presentations at scientific and public events.
- Public speaking: delivering entertaining and exciting public talks.
- Media skills: being able to pitch science news to the mass media and do good media interviews.
- Social media training: effective use of Twitter and Facebook (and visibility on platforms such as Instagram and YouTube).

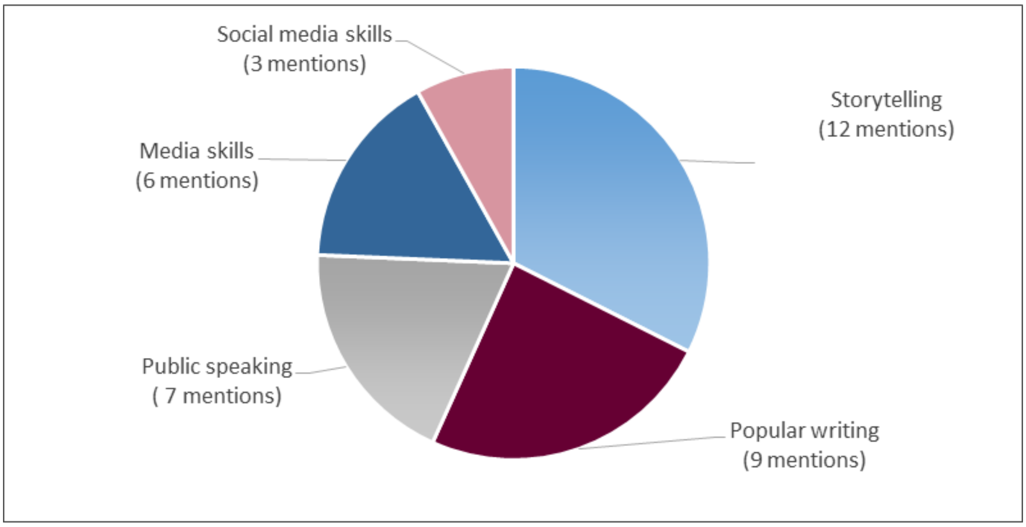


Figure 5.3: Skill set required for effective public science communication

In addition to the skills mentioned in Figure 5.3, interviewees also provided a range of examples that described their views on the characteristics or nature of effective public communication, for example:

- public speaking has to be exciting, engaging and enthusiastic;
- content has to be focused, simple, clear, digestible and easy to understand;
- materials must be relevant to everyday life, linked to the immediate context of the audience;
- scientific ideas must be illustrated by using metaphors and analogies to make connections to things that people already know in fields such as art, music and sport.

The set of communication skills and their characteristics, as suggested jointly by the 30 visible scientists interviewed for the current study, was highly similar to the required public science communication skills that scholars such as Goodell (1975), Miller and Fahy (2010), Fahy and Lewenstein (2014), as well as Illingworth and Roop (2015) suggest. None of the interviewees referred specifically to skills related to public dialogue or building trust. This is important in the light of a study by Besley *et al*. (2016) suggesting that communication training for scientists overemphasises practical skills, while it should also focus on long-term strategic outcomes.

5.2.7.5. Storytelling as a public science communication skill

> ***Factual storytelling – that is what the communication of science is.*** *(Lee Berger)*

"Storytelling is a powerful way to learn, particularly in our communities, because storytelling is how values are communicated via analogy or allegory. Tapping into that is much more powerful than didactic lectures." This is how Linda-Gail Bekker experienced storytelling as a communication tool through her involvement in participatory theatre.

Participating scientists mentioned storytelling more often than any other ability, as an essential skill required for public science communication. Using a narrative as a science communication tool (or the art of science storytelling) has attracted considerable attention from science communication scholars and trainers in recent years. For example, Dahlstrom (2014) argues that narrative formats offer increased comprehension, interest and engagement when science is presented to lay audiences; Weitkamp (2016) suggests that storytelling techniques offer a new way of making journal articles more accessible to the public. Randy Olson, a marine biologist who went to Hollywood to study effective storytelling and how this can be applied in science communication, explains and emphasises narrative arc in his science communication guides (Olson, 2009; 2013; 2015). Olson (2017) presents a case study to show the power of storytelling to give scientists a voice in the public sphere. In line with these views, several visible scientists in the current study regarded storytelling as an essential science communication skill.

> **Dave Pepler**: Science communicating is about re-discovering the art of storytelling. We are dealing in stories, not in dry, discreet clumps of knowledge. People respond to stories with a beginning, middle and end, and with humour thrown in.

> **Marcus Byrne**: The ability to tell a story – that is a key issue. You must build a thread that runs through the story, and then put beads on the thread, and make it into a product that can be consumed by anybody.

> **Tebello Nyokong**: You must tell a story, and often it must be a story in which you are a character.

> **Bavesh Kana**: When someone can tell a story that invites you into their world and takes you on a journey – that is effective and memorable communication.

> **Tolullah Oni**: When you tell a story, people lean forward and listen. It is perfectly human and we can tap into that human connection.

> **Bob Scholes**: Constructing a narrative arc is critical and we are never trained how to do that. For scientists, it is just 'methods, results, discussion, conclusion' – that the only narrative arc we know.

5.2.7.6. Moving on from peer to public communication

While acknowledging the differences between scholarly and public communication, interviewees frequently referred to the fact that communication was an integral part of being a scientist, leading them to conclude that public communication was a natural progression from communication with peers.

> **Anusuya Chinsamy-Turan**: It starts with presenting to your peers. Once you can do that, you move on to presenting to different audiences.

> **Kelly Chibale**: Scientists also need help with communicating to other scientists. It is so important that we understand each other.

By contrast, other interviewees emphasised the differences between scholarly and public communication and highlighted the need to avoid jargon, and aim for clarity and relevance when engaging with non-experts. In line with these views that public communication is distinctly different from peer communication, Baram-Tsabari and Lewenstein (2012) found that it is essential for scientists to learn the discourse of public communication in order to engage effectively with public audiences.

> **Salim Abdool-Karim**: We must learn to get away from our scientific terminology and talk clearly and simply – that is the most important thing.

> **Bavesh Kana**: As scientists, we get so involved in the nuts and bolts of our work, that we cannot see the wood for the trees. The ultimate skill is to take all that complex material and turn it into clear message.

> **Francis Thackeray**: Use language that will work for a 12-year-old. If you can do that, you can get a message across to the general public.

> **Tolullah Oni**: You have to see through the eyes of the audience and communicate in a way that makes sense to them.

Some visible scientists noted that a certain level of showmanship was required for effect in public talks and presentations, along with a need to be creative and innovative when it came to public communication of science.

> **Dave Pepler**: A great communicator lights up the audience and then stands in the glow of their experience. Even an academic lecture should be a structured performance.

> **Don Cowan**: Some of the best lecturers are also good actors.

> **Jill Farrant:** With public speaking, you really have to punch it. If you do not catch the public's attention in the first few minutes, you are dead in the water.

> **Linda-Gail Bekker**: There is some Aids fatigue on the go and to a certain extent people roll their eyes when you come with an Aids story. So, we have to sharpen our game, and find a fresh way of packaging the story. It's all about innovation. We have to keep moving ahead all the time.

Furthermore, several interviewees emphasised the importance of a solid and comprehensive knowledge of the relevant subject field as a basis for successful public engagement.

> **Tinyiko Maluleke**: You can't write a good, gripping popular piece about a topic unless you have a firm grasp of the broad subject field. In order to distil something into simple language, you need to be at the top of your game.

> **Dave Pepler**: Depth of knowledge is an absolute requirement in order to communicate science – not only in your own field, but also comparative knowledge. That is why scientists need to read widely.

5.2.7.7. Perception of self-efficacy: summary

Participating scientists valued public science communication skills, with some seeing it as a natural talent and other emphasising the importance to improve skills throughout a scientific career by participation, observation and training. While visible scientists were generally confident about their own communication skills, some of their comments about a lack of social media skills illustrated how self-efficacy influences behaviour. In other words, if they thought that they lacked the skills to perform a specific behaviour, they avoided that behaviour. Visible scientists highlighted storytelling as the most important ability that helped scientists to share their research with public audiences.

5.2.8. The influence of visible scientist's personality traits

> ***Occasionally you find scientists like myself who are complete extroverts. We are quite rare.*** *(Anusuya Chinsamy-Turan)*

> ***Going public is not an easy thing for academics. It is uncomfortable.*** *(Hamsa Venkatakrishnan)*

In this section, I present my findings from the current study about the link between scientists' personality type and public science communication behaviour.

5.2.8.1. Which personality traits make for good public science communication?

In my interviews with visible scientists, they used a range of words to describe effective science communication. As illustrated in Figure 5.4, they associated effective science communication to the public with excitement, passion, confidence, enthusiasm and charisma. Passion was frequently described as a non-negotiable requirement for effective public science communication.

The remarks about the personality traits required for effective public science communication explained the perception that passion was considered to be a key requirement.

> **Bavesh Kana**: Good communicators need one thing that can't be taught – a passion for your science. When people sense that you are passionate, that grabs them.

Dave Pepler: A passion for sharing science is a must. There is no other way for me.

Andrew Forbes: In a public talk, your passion for the topic is what matters, not so much the contents. People must become excited about the subject – that is what they will take away.

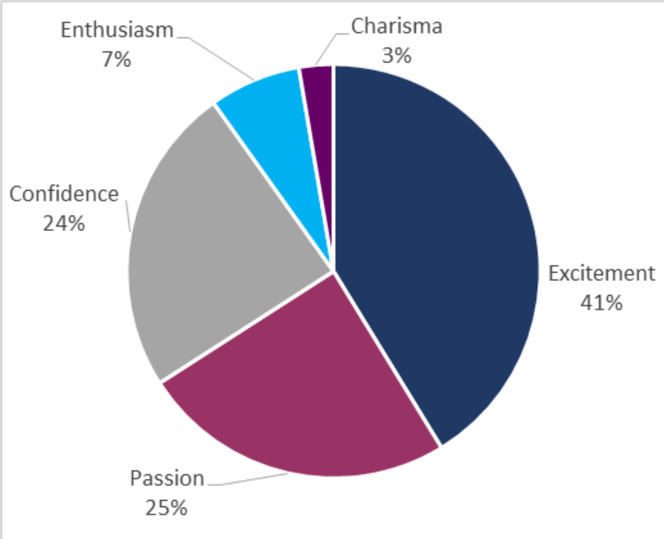


Figure 5.4: Frequency of terms associated with effective science communication

5.2.8.2. The link between personality type and communication ability

Most participating scientists agreed strongly that personality type directly influenced scientists' involvement in public science communication activities. They saw the personalities of other scientists mostly as inhibiting their public engagement efforts, but typically described pro-communication personality traits for themselves. While they thought that most other scientists were generally poor communicators, they demonstrated empathy for colleagues whom they perceived as not suited for the public stage or media limelight.

Anthony Turton: Scientists, by their very nature, want to avoid speaking to the media.

Lee Berger: Most scientists were nerds at school – often excluded and pushed to one side. As adults, scientists' personalities are apparently non-communicative.

Cathi Albertyn: Some scientists are shy and fear putting themselves out there.

Bavesh Kana: It is very hard for some scientists to be confident enough to bring attention to themselves.

Linda-Gail Bekker: I can imagine it is really hard for a reserved shy individual to get up on the stage. For them, it would feel like a punishment.

Nox Makunga: We should not force people to communicate in public if they don't have the personality for it. Some people actually choose to do science because they want to be in the lab and not in a public space.

Salim Abdool-Karim: I mean, some people just don't like communicating. Some people prefer to sit in the lab, quietly doing their work.

> **Anusuya Chinsamy-Turan**: Personality dictates scientists' willingness to share their research. Some people are more open and enjoy talking to others. In general, scientists are introverted and prefer to work alone and do things in their own space. They don't want to be bothered by people.

> **Tebello Nyokong**: I think it really depends on the character of the person. Some people are shy to talk in public.

These observations were in line with the stereotypical view of scientists as isolated from society and uncomfortable in public spaces, as described by Goodell (1977).[75] They furthermore fit the finding by Rödder (2012) that many scientists (in this case, scientists who are not publicly visible) refer to themselves as being media-shy.

Byrne pointed out that forcing scientists who were not well suited to public communication to play this role, could reinforce a negative stereotype of scientists in the public's mind.

> **Marcus Byrne**: Because, as in any field, there are people who are not really that good with talking to other humans. And there is always the danger that you are going to reinforce a stereotype of the nerdy scientist who does not have a clue about communicating with anybody.

However, when visible scientists referred to themselves, they mostly described personality traits that aided effective communication.

> **Himla Soodyall**: I think I have a personality that is user friendly to people from the outside.

> **Anusuya Chinsamy-Turan**: I think that part of my character is being able to share my experiences.

> **Linda-Gail Bekker**: When I'm in a room with other scientists, I'm always the spokesperson. My personality is suited to the role and it comes naturally to me. I am, as my family refers to me, a drama queen.

> **Tebello Nyokong**: I've always been the drama queen.

Visible scientists also highlighted personality traits in a few (selected) fellow scientists whom they perceived as positive in terms of public communication. Interestingly, the individuals they referred to (people such as Lee Berger, Linda-Gail Bekker and Anusuya Chinsamy-Turan) were also interviewed for this study.[76] Their comments highlighted the personality traits that they perceived to be ideally suited to public science communication.

> **Glenda Gray**: Some scientists are just wonderful communicators. Linda-Gail Bekker is just spectacular! She comes across well on television; she has a nice voice; she is eloquent and she is just incredibly engaging. If I had to put anyone on TV, I would choose her.

[75] Note: Goodell (1975; 1977) finds that this stereotype does not apply to publicly visible scientists.

[76] The scientists I interviewed did not know who else I spoke to in this study before I interviewed them.

> **Bruce Rubidge**: Anusuya Chinsamy-Turan has the personality to engage with the public. She knows what she wants to say and she does it so well. And that is also why Lee Berger is so successful. He is hugely exciting.

The way that these visible scientists described themselves and other visible scientists, resonated with Goodell's (1975) descriptions of visible scientists as articulate, colourful, outspoken, charismatic and people who thrive at the centre of attention. It also confirms the finding by Tsfati *et al*. (2011) that scientists' personality traits predisposed them to attract or avoid publicity.

While most visible scientists saw a direct and strong connection between personality type and public communication behaviour, some pointed out that being introverted did not necessarily mean that you could not participate in public communication. In our interview, Linda Gray, for instance, repeatedly said that she was stressed by media interactions. She described herself as a sociophobe. Yet, as MRC president, she is arguably one of the most visible scientists in South Africa and she enjoys considerable international visibility.[77]

Along the same lines, some interviewees described themselves as introverts who learned how to communicate in public, while Farrant similarly believed that she acquired public communication skills due to circumstances that demanded of her to become used to public attention. The idea that introverted individuals are able to become excellent public communicators is supported by Cain (2012), Weiler *et al*. (2012) and Rosen (2016). That is why, for the purpose of the current study, personality type was considered an attitudinal factor, i.e. something that is within the power of the scientist to overcome.

> **Dave Pepler**: I am intensely private. My persona on television and radio has no bearing on my true self. It is absolutely not true that you have to be an extrovert to be able to communicate in public. It is a simple technique.

> **Tebello Nyokong**: I am the most introverted person you will ever meet, but I taught myself to be an extrovert in public. As long as people are more than two metres away from me, I'm fine.

> **Bob Scholes**: I am intrinsically an introverted person, but speech therapy and experience got me over the fear barrier.

> **Jill Farrant**: It is important to get out of your comfort zone. Confidence comes with time. I was never such an open and easy communicator, until I was forced to do it because of various awards that I received.

For Farrant, being a good communicator was also about standing out from the crowd, with comments that reflected an outgoing personality type.

[77] Gray was named as one of 100 most influential people in the world for 2017 by *Time* – see https://www.wits.ac.za/news/latest-news/research-news/2017/2017-04/glenda-gray-on-time-100-list.html.

Jill Farrant: I am quite eccentric and will dress up for a public presentation. I put on fancy music and I'm not scared to make fun of myself. And, I always wear a feather in my ear. You have to be creative to put your subject across in a sexy way.

5.2.8.3. Personality traits: summary

The visible scientists in the current study displayed a range of personality types, but typically did not fit the stereotype of scientists as introverted and socially awkward individuals. Interviewees characterised successful public science communication (and communicators) as exciting, passionate, confident, enthusiastic and charismatic. While most visible scientists saw these characteristics in themselves and in some fellow scientists, they thought that most scientists were shy and fearful about communicating in public. Some visible scientists claimed that they were introverts who were only successful at public communication because they were willing to step out of their comfort zones and put effort into developing and honing their communication skills.

5.2.9. The influence of perceived communication rewards

Without public visibility, I would have just been a quiet little rat sitting in my little hovel minding my own business. I mean, someone like you would not be calling me. *(Himla Soodyall)*

If you sit in your little office and don't tell anybody what you are doing, you are sounding the death knell on your field of science. *(Bruce Rubidge)*

In this section, I review the evidence from the current study about whether and how scientists' public communication behaviour is shaped by perceived rewards, both intangible (or intrinsic) rewards as well as the tangible (extrinsic) rewards.

5.2.9.1. A nuisance at times, but ultimately worth it

"Scientists are indirectly judged on how well they communicate, they just don't realise it," Andrew Forbes said about how he perceived the rewards of external communication. "Good communicators get promoted faster," Berger agreed. Scholes and Rubidge told me how they often perceived these activities as troublesome at first, but ultimately worthwhile in the long run.

Mary Scholes: Sometimes, doing public talks can be enormously inconvenient. You know, they invite you to go to the garden club in Bronkhorstspruit on a Friday night at 6 o'clock. You sit in the Johannesburg traffic for two hours and when you get there, there are four old ladies and they want to talk to you about their pansies. So, you are kind of irritated. But then, you find out that one of them is the grandmother of a Nobel Prize winner and you feel so good that you made the effort. You actually feel bad about being grumpy at the beginning. Usually, you get more out of it if you are prepared to listen to them.

Bruce Rubidge: Sometimes it is a bloody nuisance to be called to another garden club meeting. But, I made it a rule early in my career that I would try to go every time that I am asked to talk. I made that an obligation on myself. I have another one tomorrow night. I do it all the time, and it gets in the way of family life and other things. But, it is so important. If one person in that garden club is affected by what you say, it is all worth it.

All the other scientists I interviewed agreed that they found some aspects of public science engagement rewarding at a personal level, and something that "one never regrets", as Berger put it. These feelings of satisfaction and personal fulfilment relayed by the interviewees in the current study were in line with findings about the intrinsic rewards of public science communication by Dunwoody *et al*. (2009) and Dudo (2013). In the next section, some of the most important intrinsic and extrinsic rewards that scientists in this study perceived from engaging with external audiences are described.

5.2.9.2. Making a difference

Studies of scientists in other countries show that they derive meaning and self-esteem from making a contribution to the public good and that, for most scientists, their willingness to share their work with public audiences is rooted in their desire to promote science literacy and fuel future discoveries (Pearson *et al*., 1997; DiBella, 1999; MORI, 2001; Andrews *et al*., 2005; Pace *et al*., 2010; Searle, 2011; Dudo *et al*., 2014; Kuehne *et al*., 2014). Likewise, scientists interviewed for the current study were motivated by the prospect of making a positive contribution to society, and they found personal rewards in the idea that they were somehow making a difference to other people's lives.

> **Linda Richter**: Going through a public consultation process on a new policy is demanding, but it is also deeply satisfying to think that you are actually making a difference. That day when Cabinet signed off on The Early Childhood Development Policy – it was a huge thrill!

> **Amanda Gouws**: For me, it is important to feel that I make a difference. And, I can only do that if I am part of the public debate. And, when I look back on my life, I want to be able to say that I did make a difference.

> **Bob Scholes**: When I interact with the public, there is a feeling that you are making a difference and that you are somehow contributing towards some greater good.

> **Anthony Turton**: I'm at the cutting edge of something and I am making a difference somewhere. That is the energy that fuels me as a person.

> **Don Cowan**: We are scientists; we love science; we live for science. So, getting it out there, feels good. The reward is a warm, cuddly feeling that you are doing some good.

Public reaction, often in random places and at random times, was perceived as meaningful and it motivated interviewees to continue with public engagement.

> **Tim Noakes**: People say things such as 'You have changed my life' and 'You saved my life.' When I went through a really bad patch about a year and a half ago, that public feedback kept me going. I knew that the public respected and appreciated what I was doing.

> **Tebello Nyokong**: I was on the radio, and then a policeman came on the line and said: 'After listening to you, I am going back to school.' So, even if he was just one out of so many, it was important to me that I could inspire someone to improve himself.

Lee Berger: I have driven into petrol stations and people go 'You're that guy who discovered Naledi' or 'Your son found that fossil'. These people struggle to make a living, and yet these scientific discoveries give them something in their lives that is beyond that.

Anusuya Chinsamy-Turan: Every now and again I bump into somebody that was inspired by one of my talks to study science. I can tell you some wonderful, cool stories … and they are always so grateful that I fired up their imaginations to become scientists.

Similar to the rewards described by interviewees in the current study, earlier studies found that scientists perceive public communication as a worthwhile and socially important activity that matters to them on a personal level (Miller & Fahy, 2010; Searle, 2011). As pointed out by Kuehne *et al*. (2014), it is difficult to quantify the fulfilment and motivation that scientists derive from public engagement, but it is clear that these activities have significant meaning and value for many of them.

5.2.9.3. Simply for the fun of it

When asked 'What's in it for you to spend time and effort on public engagement?', many visible scientists said that they did it simply because they enjoyed it, even if they did not perceive any tangible rewards from being involved. Earlier studies confirm that many scientists find public engagement enjoyable (MORI, 2001; Andrews *et al*., 2005; Holliman & Jensen, 2009; Kreimer *et al*., 2011; Searle, 2011; TNS-BMRB, 2015).

Marcus Byrne: The rewards are the fun and getting science to the general public. That is what is important.

Don Cowan: Presenting at 'Science and Cocktails'[78] was fun. I really enjoyed it!

Marcus Byrne: When I say, 'Look, isn't it fascinating that this little animal can do this', invariably most people will go, 'Wow, I never knew that!'. I enjoy explaining things to people.

Linda-Gail Bekker: I enjoy the interaction with people. I feel validated in my work if people say, 'Wow, that is fascinating!' That is my reward.

Anusuya Chinsamy-Turan: There are certainly no brownie points for doing all this, but I just love it. I just enjoy sharing my knowledge with other people.

Bavesh Kana: I love working with the mass media. When you arrive in the studio, they sound check you and the adrenalin starts pumping. It makes me feel alive.

Interestingly, some scientists noted that they still became anxious about public speaking before events, but added that they found it rewarding once they got started.

Cathi Albertyn: I am terrified of public speaking, but when I get into it, I really enjoy it.

Jill Farrant: I get nervous as hell before a talk, but I love it afterwards.

[78] A public science engagement event (see http://www.scienceandcocktails.org/jozi).

5.2.9.4. Feeding on audience feedback

"When people say after a talk, 'oh, that was really so nice', it's like a pat on the back, and that is the reward for going back," Makunga told me. Similar to the findings of earlier studies (Pearson *et al.*, 1997; The Royal Society, 2006; Wilkinson *et al*., 2011), interviewees delighted in the immediate feedback that they received from audiences during and after a public talk. While scientists generally use a wide range of platforms to engage with external audiences, their preference for direct interactions with people have been demonstrated before (e.g. Agnella *et al*., 2012). Kuehne *et al*. (2014:1227) describe immediate feedback from public audiences as "a reinvigorating contrast to the (relatively) slow appreciation arising from the process of research, peer-review, and revision". In line with this view, visible scientists in the current study were motivated by audience interactions.

> **Andrew Forbes**: To see people get excited about what you do is a wonderful feeling.
>
> **Bavesh Kana**: I feel that I have accomplished something when I see that people understand what we do.
>
> **Dave Pepler**: My greatest achievement is to empower people – to suddenly see that they understand; to see their eyes light up. That is the reward of communicating science.
>
> **Anusuya Chinsamy-Turan**: I love the interaction with the audience after a lecture. That is when I see whether I got them thinking in a different way. I enjoy it when people feel happy about learning something new. I am so thrilled when I see that spark lit in somebody.
>
> **Francis Thackeray**: It is a thrill to see how the audience reacts.
>
> **Jill Farrant**: It gives me great delight to interact with an audience after a talk and to be able to dispel the concerns of the public.
>
> **Kelly Chibale**: I tap tremendous energy from the connection with the audience. Their concentrated focus just gives me a lot of joy. And, when many of them stick around wanting to talk some more, then I really feel that I have touched them.
>
> **Andrew Forbes**: I want people to get excited and remember that it was an amazing talk. That is the only thing I want to get out of it.

In particular, many visible scientists enjoyed engaging with children and young audiences, and desired to inspire them about science.

> **Don Cowan**: When we speak to a group of learners, we hope to tweak some excitement and inspire a few.
>
> **Kelly Chibale**: I really get a kick out of young kids being fascinated about what we do.
>
> **Bavesh Kana**: I absolutely love working with children. It is really special to see the wonder in their eyes when we show them what we do in the lab every day. It really gets me ticking.

> **Marcus Byrne**: Tiny kids of three or four years old come to our 'Yebo Gogga'[79] events that we've been running annually for nearly 20 years – and you can see the kids love to learn about spiders and insects.

Given the nature of their research, health scientists perceived community-level engagement as particularly important and meaningful.

> **Linda-Gail Bekker**: When I take young researchers with me into communities, they experience why their research has relevance. They tell me how much it means to them, and how valuable it is. Because, they are lost and isolated in the lab working on an animal model or a molecule. Interacting with communities re-invigorates them. All of us should have a healthy dose of community every now and then. It is really important.

The view that community engagement could help young researchers to see and value the broader context of their work is also highlighted in research by Illingworth and Roop (2015).

My interview data showed that visible scientists typically found it rewarding to share their passion for their science, and the excitement of doing science.

> **Francis Thackeray**: In palaeontology we really must relay to the public the adventure and excitement of a discovery – that is what our science is all about.

For some visible scientists, the personal reward of public engagement was linked to their goal of making people more aware of their specific research topic.

> **Nox Makunga**: I like sharing my research and, hopefully, getting people interested in our plants and the way people use them.

> **Bruce Rubidge**: It is a really good feeling when the audience loves your talk and when they say, 'Wow, what a fantastic heritage we have in South Africa!'

> **Bavesh Kana**: I really want people to know about the TB research we are doing in my lab. I feel a need to be understood, to not be irrelevant.

5.2.9.5. Reflecting on own research

Over and above the personal rewards outlined above, visible scientists perceived that engaging with public audiences could be helpful to their research, providing them with new meaning, perspective, inspiration, and ideas for future studies. Having to present their work to lay audiences forced them to distil their ideas, while they also got new ideas and information from the public.

> **Bob Scholes**: Last year I did my inaugural lecture at Wits. And, you are not meant to be speaking to fellow academes, you are talking to the broader community and you are supposed to give a synoptic survey of your life's work. I found that a wonderful challenge, and I thoroughly enjoyed it. Standing back and doing that actually forced me not only to think about what it is that I do and why I do it, but how do I put that in a way that my mother can understand. Because my mother was in the audience.

[79] This is a public engagement event at University of the Witwatersrand (see https://www.wits.ac.za/yebogogga/).

Bavesh Kana: To explain the nuts and bolts of your research to people who have no idea of your research, really makes you think very carefully about what you are doing, right?

Nox Makunga: You never know where inspiration or new ideas will come from. Engaging with the public definitely generates new ideas.

Cathi Albertyn: To engage with the public, you have to present your work in simple language and come up with sound bites for the media. It is a way of getting on top of your research and working out the most important points. It sharpens your mind and your ideas.

Hamsa Venkatakrishnan: It is good to engage with people who don't see the world in the same way that you do. It enriches my academic work, because it forces me to confront questions that I might not have to confront otherwise.

Linda Richter: There are many sources of information, and you can get new perspectives on problems and new ideas for research from talking to ordinary people.

Sheryl Hendriks: Sometimes journalists come with quite tricky questions. They make us think about the 'so what?' of our research.

Cherryl Walker: Having to articulate ideas in a different way is a good way to ask yourself: What do I actually mean? Do I really know what I'm talking about here? And, you get really challenging questions from the public.

Marcus Byrne: People are natural observers. They are watching the birds around them and they are watching the 'goggos'[80] climbing into their houses at night. And they will tell you stories about them. Joe public can be a fantastic source of information.

Likewise, the notion that public engagement could provide new ideas and renewed enthusiasm for research is also evident in studies by Pearson *et al*. (1997), DiBella (1999), Burchell *et al.* (2009), Searle (2011), Dudo *et al*. (2014) and Flaherty (2016). From her study of Belgian scientists, Van der Auweraert (2008) concludes that the process of communicating with lay audiences triggers a thought process whereby research ideas and questions are clarified, leading to improved insight into future research. On this topic, Baron (2010b:1033) states:

> In my work with scientists, I often hear that they cannot afford the time to work on their communication skills, with their hectic research, publishing and teaching schedules. I see it another way: they cannot afford not to. Being a good communicator is not a trade-off. It makes you a better scientist.

Visible scientists, along with their research teams, also told me how they found motivation in being seen and heard in the mass media and social media.

Sheryl Hendriks: It creates huge group excitement when we get positive feedback from the public. So, we monitor the statistics on how many 'likes', 'follows' and 'reposts' we get. And, when I arrive in the morning I hear, 'We have a new piece out on The Conversation, or someone heard one of their colleagues on radio. It creates group cohesion and a feeling that what we are doing is worth it.

[80] 'Goggos' is a colloquial term for insects and spiders, from the Afrikaans word 'goggas'.

"I suppose there is a certain amount of ego in it as well. But, I try not to be ego-driven," Rubidge remarked. Several more interviewees readily acknowledged that a part of the reward they perceived from public engagement resulted from a perceived boost to their egos.

> **Marcus Byrne**: As scientists, our egos are fed when we see the light come on in our students' eyes. I get that same kick from bringing nature into people's lives. There is a lot of ego involved when scientists communicate in public. There has to be.

> **Cherryl Walker**: There is some satisfaction and ego and seeing your name in print, especially when you are pleased with the article.

> **Don Cowan**: Presenting on stage is certainly a boost to the ego. Don't ignore the ego.

> **Jill Farrant**: There is always some ego involved. When people come to you and say, 'That was fantastic, we really appreciate it', of course, it makes you feel good.

Other scholars are critical of scientists who engage with public audiences for egotistic reasons. For example, Martín-Sempere *et al*. (2008) suggest that a desire for public prominence may become a motive in itself when scientists aim to boost their own egos, and this is often linked to scientists who seek to promote themselves in order to compete for public attention and resources (Weingart & Guenther, 2016). One of the visible scientists in the current study agreed that this was a risk.

> **Mary Scholes**: Some scientists may communicate all the time simply because it boosts their own ego – and we all know how many scientists there are in that box. They make their work a lot more sexy and exciting than it really is and end up not necessarily telling the whole scientific truth, with many unintended consequences.

5.2.9.6. Tangible rewards

Over and above the intrinsic (or intangible) rewards discussed above, scientists also perceived concrete (tangible) rewards from their involvement in public communication activities, in particular legitimisation of and a favourable climate for research activities, financial support and an improved image of science and scientists. The perception of such rewards can be powerful motivators for sustained involvement (Van der Auweraert, 2008; Tsfati *et al*., 2011; Rödder, 2012; Dudo *et al*., 2014). The potential of public communication to boost recognition, also by fellow scientists, is widely accepted (e.g. Peters, 2012; Smith *et al*., 2013; Massarani & Peters, 2016; Namihira-Geurrero, 2016). Most visible scientists in the current study saw a definite link between their public and academic visibility, and explained how their communication efforts have boosted their recognition in public and academic circles, and increased the uptake of their work.

> **Tolullah Oni**: The narrative around public engagement is changing. It is no longer seen as a big sacrifice. It has real benefits in terms of recognition in our inter-connected world.

> **Cathi Albertyn**: I am generally known and respected in my field. That comes from my academic work, but some of it also comes from being in the media. And, the more visible you are, the more people will think of your name when they need high-level advisors and committee members. So, there are definite career spin-offs that come with public visibility.

Amanda Gouws: The fact that I am well known, contributes positively to my academic career. I'm contacted from far and near. It opens doors. It gives me opportunities and recognition as a public intellectual.

Himla Soodyall: The media exposure has made this science popular and now, by public demand, we are able to offer genetic ancestry testing as an offshoot of my research on population radiation in Africa.

Competition for funding was widely recognised as one of the drivers of public science communication. Several scientists in the current study have experienced how public visibility has resulted in increased funding.

Tim Noakes: This Sports Science Institute is the result of public communication, and my book *The lore of running* which was based on my popular columns. That is what we used when we went fund-raising for building the Institute. That was very important. I would never have got where I got in science without being very public.

Francis Thackeray: It was a special moment in my career when I was called to the ministry of Arts, Culture, Science and Technology and told to 'think big' with a proposal for supporting palaeontology at the Transvaal Museum. I think it happened because the decision-makers were aware of my dream to have a replica of the skull of Mrs Ples in every classroom in South Africa.

Bruce Rubidge: I would imagine that our public profile certainly helps to bring in funding. It really helps to be known before you arrive at a funder.

Jill Farrant: Being visible has definitely resulted in new collaborations for me. It is incredibly valuable to have top people in the world interesting to work with you, and it often extends to extra funding.

Kelly Chibale: I get approached by international organisations wanting to set up new projects here. They would not have been aware of us as potential collaborators if we did not invest in communication.

Andrew Forbes: Funding decisions are usually made by peers who serve on panels at funding bodies. They have a good feel for who is visible and who is not. So, public visibility can make a difference. It definitely can't hurt.

Earlier studies that have demonstrated the potential of public science communication to yield funding returns, include MORI (2001), The Royal Society (2006), Wigren-Kristoferson (2011), Palmer and Schibeci (2014), Dijkstra *et al*. (2015), France *et al*. (2015) and Koh *et al*. (2016).

Several visible scientists acknowledged public communication as an important fundraising tool that mattered increasingly to research funders.

Linda-Gail Bekker: If you plot TB research funding, you will see that it usually follows some crisis or public outcry. So, with every splash in the media, funding goes up for a while. That means we have a responsibility to keep the public ear to the ground.

Nox Makunga: It is essential for industry leaders to understand the potential and impact of science, because they can contribute financially.

> **Kelly Chibale**: Instead of expecting politicians to solve our problems, perhaps it is time to turn things around and let politicians see the value of what we do.

> **Pumla Gobodo-Madikizela**: Funders like it when you make your work visible, because then you are also making visible the fact that they are supporting this kind of work.

Berger, however, experienced that fellow scientists did not like it when their peers raise money via science communication, probably resulting from professional jealousy.

> **Lee Berger**: The idea that there is something wrong with public communication is not going to go away soon. We have to live with that, because it is advantageous for a small group of very powerful public communicators in science not to have a lot of competition. So, money is a dirty word, don't talk about it. You never can talk about it.

Several visible scientists emphasised the idea that communicating to the public was at once also a way to reach other scientists, and that public communication escalated academic visibility.

> **Tolullah Oni**: Other scientists are also part of the publics we engage with. We should not separate it. You also connect to fellow scientists by connecting to society.

> **Lee Berger**: We have bastardised the term 'public' to somehow exclude scientists. Scientists are part of the public too.

> **Jill Farrant**: I have no doubt that other scientists discover my work via non-academic platforms, such as my TED talk. That's where they see me, and they look for my papers.

> **Hamsa Venkatakrishnan**: When academics have a big social media profile, I see that they can use that to increase the number of people who read and cite their work.

In line with the observation by Venkatakrishnan, studies found that social media exposure has the potential to amplify academic influence by boosting article downloads and/or citations (Eysenbach, 2011; Priem *et al*., 2012; Brossard, 2013; Liang *et al*., 2014).

5.2.9.7. Absence of tangible rewards

Notably, not all scientists perceived tangible benefits from public engagement, since that means that concrete rewards such as money or prestige were not a prerequisite for their involvement in public communication activities.

> **Don Cowan**: If there are tangible rewards, they are not immediately obvious.

> **Tinyiko Maluleke**: To be honest, the benefits are not that great. Scientists benefit more from engaging with their peers and there is no greater accolade for a scientist than to be recognised by fellow scientists.

> **Marcus Byrne**: Clearly, my public visibility has done me no good whatsoever with the NRF ranking system, and I have not generated any research money directly from it either. All of my research money is linked to bio-control of alien weeds, but my public communication is mostly about dung beetles. So directly, I have definitely had no benefit from generating research funds. So, I think that is in some ways quite a good thing. It shows that it does not have to be for the money.

5.2.9.8. Perceived communication rewards: summary

Participating scientists acknowledged that public engagement activities were sometimes inconvenient and time-consuming, but, on the whole, most visible scientists perceived a range of tangible and intangible benefits from being involved in these activities that made it worth their while. Even those who perceived no concrete rewards experienced the intrinsic rewards such as enjoyment, self-fulfilment and meaning. Additionally, scientists found that they occasionally gained useful information from interacting with the public, including valuable perspectives on their own work and ideas for new research. It was evident that both abstract and concrete rewards that scientists perceived from public science communication sustained their public communication efforts.

5.2.10. The influence of perceived communication risks

There are no obvious risks, unless you are naïve.
(Don Cowan)

To say that there are no risks, is naïve.
(Bavesh Kana)

Based on my interviews with 30 visible scientists in South Africa, I explored the evidence that scientists associated risks with public science communication, and how this influenced their behaviour in this regard. I used the contrasting remarks made by Cowan and Kana (introduced above) to illustrate that visible scientists in the current study perceived very different levels and kinds of risks when it came to going public with their research. The majority view was that there definitely were some risks. For example, Gouws said, “There are always risks,” and according to Kana, “Things can go horribly wrong and there are consequences.” Despite these perceptions, many visible scientists felt that the benefits offered by public communication outweighed the risks.

The findings of the nature and origins of scientists’ perceived risks and the fears that they associated with public communication, corresponded with what was revealed by earlier studies, namely that some scientists view public communication of science as potentially difficult and dangerous (Davies, 2008); an activity that occasionally have unintended, adverse consequences (Porter *et al*., 2012; Johnson *et al*., 2014; Burchell, 2015) and these negative experiences lead to unease about future public engagements (TNS-BMRB, 2015). Similar to findings from the literature, the risks and fears that visible scientists in the current study associated with public science communication were not universal, but rather depended on the type of activity and circumstances. They used words such as ‘anxious’ and ‘nerve-racking’ to describe how they felt when contemplating these risks.

5.2.10.1. Being misunderstood

Scientists generally fear the possibility that what they say or write will be misunderstood or misrepresented (Gething, 2003; Poliakoff & Webb, 2007; Dunwoody *et al*., 2009; Allgaier *et al*., 2013b; Pew Research Center, 2015; Rogers, 2015). A similar fear was evident in the current study.

Tolullah Oni: Say that your words end up being distorted – that is a huge mental barrier to engaging.

Salim Abdool-Karim: The biggest risk is that the information you convey is misinterpreted.

Kelly Chibale: Being misunderstood or misquoted can be very damaging – not only to you, but also to your institution. And you are guilty by association, even if it wasn't you.

Lee Berger: Miscommunication of your science is a huge risk. Once an error creeps into the media, it gets repeated over and over.

Interviewees also realised that, from time to time, they could be wrong themselves and they were understandably concerned about being mistaken in a public arena.

Marcus Byrne: Scientists are supposed to be the voice of authority, trading in knowledge, but we are not always good at it and we get stuff wrong.

A related fear was that, under certain circumstances, visible scientists were aware that they might say something that they would regret at a later stage.

Dave Pepler: I have a quick mouth, and sometimes terrifying things get out, which I did not mean in context.

Cathi Albertyn: I have been pushed into positions where I have probably said more than I wanted to say.

Glenda Gray: I am very good at being provocative and saying things that get me into trouble. During the Aids denialism debate, I got into lots of trouble when I said in public: 'What does Mbeki want us to do – should we throttle these babies at birth?' Well, at the time, I did feel that it would be more humane to do that than to inflict HIV on them. And so, of course, the journalists love that kind of sound bite and I was in hot water.

Visible scientists who participated in the current study also experienced challenging interactions with the public around some of the controversial aspects of science.

Francis Thackeray: Occasionally, at the end of public lectures, I get questions that are really hard to answer, particularly on the topic of religion and palaeontology.

Several visible scientists emphasised the need to be absolutely honest when communicating with public audiences, and to avoid hyping up research findings at all costs. These concerns were closely linked to safeguarding an individual reputation in science.

Bruce Rubidge: If you blow up your science too much and you make it bigger than what is credible, that is very negative and draws huge criticism. Scientists have to be very careful. Once you have a reputation of not having integrity, it is very difficult to restore that credibility in the scientific community. You might be able to blunder over with the public and some funders. But, when it comes to fellow scientists, once you have blown it with them, you don't get it back again.

Interviewees regarded honesty and transparency as vitally important when it came to the communication of research projects that did not yield the results that researchers had hoped for.

> **Glenda Gray**: You have to be honest and transparent when trials go wrong. You must never hide negative or adverse research findings, because they will come back to bite you.

In line with these findings, earlier research found that scientists who have a high public profile are frequently concerned about a backlash from their colleagues and peers (Mathews *et al*., 2005; Searle, 2011; Ecklund *et al*., 2012; Porter *et al*., 2012). Scientists participating in the current study who have experienced intense negative comments from peers after going public with their views and findings included the two most visible scientists identified here, namely Lee Berger and Tim Noakes.

5.2.10.2. Being attacked

"To write for the general public is to take one of the greatest risks a scholar can take," Maluleke said during my interview with him, "because anybody, including people with very little knowledge of the subject that you are writing about, can respond in public that you are talking nonsense". Scientists who worked on controversial topics occasionally experienced public repercussions resulting from their scholarly views.

> **Cherryl Walker**: I have been attacked quite viciously from time to time for views expressed in public. I suppose it goes with the territory.

> **Amanda Gouws**: I receive hate mail and some of the things people tell me are totally deranged. I've learnt to live with it.

> **Bob Scholes**: There are denialists out there and it does get personal and robust sometimes, but not to the degree that it does in the US where colleagues of mine have had their careers destroyed by congressmen going after them.

However, none of the visible scientists in the current study had reason to fear for their personal safety as a result of public communication, such as threats of violence, sexual assault or attacks on family members that have been reported for Australian climate scientists (Searle, 2011). Tim Noakes, however, felt that the personal attack on him was driven by industry and that it was "almost as bad as a death threat".

5.2.10.3. Fears about media and social media[81]

"Don't think of the media as a neutral partner," Turton said. "You have to understand how the media work, or they will burn you." As has been shown by earlier studies (Van der Auweraert, 2008; Pew Research Center, 2015; TNS-BMRB, 2015), several visible scientists in the current study perceived media interactions as potentially dangerous. The perceived risk was mainly based on their perceptions of not begin able to control the final message when they communicate via mediators.

> **Mary Scholes**: Often, the media intentionally set up a panel discussion to highlight controversy and conflict. So, they will set me up against a climate denialist, for example.

[81] Perceived risks associated with media and social media are discussed in 3.3.4 and 3.3.5.

> **Salim Abdool-Karim**: When journalists are sloppy and write an inaccurate story, it takes a huge effort to undo the damage.
>
> **Cathi Albertyn**: Journalists push you to say things, because they are interested in a scoop.

Media concerns recurrently related to the timing of releasing new information and the demands from the media for news about scientific breakthroughs. This corresponded with scientists' fears that premature leaking of scientific results to the media could jeopardise their chances of getting the research published in a high-quality journal (Fink, 2016; Massarani & Peters, 2016).

> **Francis Thackeray**: A big risk with high-profile stories is that journalists may break the embargo, and then there is a serious danger that a journal may refuse to publish the science. And sometimes, you may give a glimpse of an unpublished research finding in a conference, not realising that there are journalists in the audience.
>
> **Tebello Nyokong**: A lot of misinformation gets out when journalists demand information too early, before we have final results.
>
> **Salim Abdool-Karim**: In science, we solve problems all the time, but it is often a very long road before we have a new solution that the public can use. We make meaningful discoveries along the way, but it may be years before we have anything with applications to patient care. In the meantime, the media wants positive news.
>
> **Glenda Gray**: I worry that if we do too much media engagement while the research is ongoing – particularly for HIV vaccine trials – we create expectations and it will be so much more devastating when we do not achieve the research outcomes we were hoping for. I think that the whole HIV vaccine thing got out of hand last year, and that there was just too much hype about it. And I would have liked to have taken us down a notch or two.

While some scientists interviewed for this study perceived the role of the media in hyping up scientific findings as a risk, other were equally aware that scientists themselves were at risk of overselling their findings. Tebello Nyokong identified 'overselling' as one of the biggest risks of media interactions and warned that scientists have to be particularly careful not to overrate their achievements. These concerns about the dangers of hyping up scientific findings in order to achieve media interest relate to concerns about medialisation of science (Weingart, 1998; Peters et al,. 2008; Rödder, 2011 & Weingart, 2012).

"How many academic careers have ended up shipwrecked on the shores of a Facebook post or a tweet?" Berger replied when I asked him about perceived risks of public science communication. Kana agreed, "you can get damaged in the social media space and it may be hard to come back from that".

In addition to the reputational damage that could result when public communication of science goes wrong, visible scientists worried about its time demands. In particular, they were concerned that, if they appeared to be spending too much time on public engagement, this could detract from their academic progress. This is clearly linked to the considerable pressure that academics perceive to publish in peer-reviewed journals, which was also highlighted as a potential barrier to public science communication in the studies by The Royal Society (2006) and Van der Auweraert (2008).

> **Nox Makunga**: Sometimes, I probably do too much science communication, and this takes me away from publishing a paper which obviously is important for my academic career. Also, you don't necessarily want to become a celebrity scientist because then your peers may not take you seriously. It becomes a push-and-pull situation. You have to find that balance.

> **Tolullah Oni**: We have a small pool of scientists who communicate, so they become over-used in the public arena.

> **Mary Scholes**: When you communicate well, you get drawn into a number of different activities. There is a risk that you fly all over the world and do fun things, but eventually lose your academic credibility.

These fears about the loss of academic credibility that may result from excessive involvement in public communication surfaced regularly in earlier studies (Miller, 1998; Jacobson *et al*., 2004; Martín-Sempere *et al*., 2008; Ecklund *et al*., 2012).

Byrne expressed a different concern, also linked to the demands of public communication, but which focused on the fear of becoming stale in the public arena, which is a concern that has not surfaced in earlier studies.

> **Marcus Byrne**: You're only as good as your last performance, but you have to keep on feeding the machine, and there is a danger that you get caught up in feeding the machine. Science does not cough up sexy results on a regular basis, so eventually you ask yourself: 'Am I beating the same drum? Is this getting boring?'

5.2.10.4. It is complicated

When speaking in public or speaking to the media, scientists frequently experience pressure to present their work as simply and succinctly as possible, leading to concerns that the audience may misunderstand them, or that they may be accused of oversimplifying science. This was evident in the current study and is also mentioned in earlier research (MORI, 2001; Weigold, 2001; Treise & Weigold, 2002; The Royal Society, 2006; Poliakoff & Webb, 2007; Winston, 2009; Besley & Nisbet, 2013; Cribb, 2011). Remarks from Makunga and Abdool-Karim illustrated some of the challenging situations they have faced when communicating in public.

> **Nox Makunga**: Some people think that in a 30-minute talk they will learn everything that there is to know about medicinal plants. In South Africa alone, we use at least 4 000 different plants, and some of them are potentially harmful. So, it can be a treacherous task to talk about these things in public.

> **Salim Abdool-Karim**: As scientists, we have our own language and terminology, which make it very hard to explain some things to the public. For example, to talk about HIV, you have to talk about antibodies. But, you can't just assume that people will know what an antibody is. So, you have to explain it. That takes two to three minutes, but the media only gives you a few minutes for the whole story. Sometimes, they want just a 30-second clip.

5.2.10.5. A few horror stories

Several scientists in the current study shared stories of how public communication went wrong in the past, and what they had learned from that. The unintended and unexpected consequences that resulted from communication events (as captured in these stories) illustrate potential risks of public science communication.

> **Glenda Gray**: I did not realise that whenever you meet a journalist – whether you have an appointment for an interview or not – you can be quoted. I was in the US about an HIV vaccine trial that had gone wrong. I walked into the meeting room and said to someone that I did not sleep the night before and had a terrible headache. A journalist from *The Washington Post* who was there to interview me later heard that – and that became the story. I was really upset and so was the NIH [National Institutes of Health], the funder of the study. So, I learnt that when you have bad news, do not show your feelings, no matter how hard it is.

> **Cathi Albertyn**: There is a place for emotion in public communication, but you have to be very careful. I once did a radio interview about abortion. It was late at night; I had young children and I was tired. And then there was this onslaught of people telling me that women who choose abortion were baby killers. I just got angry and it did not turn out well. It was the wrong thing to do.

> **Andrew Forbes**: A journalist phoned me to ask about applications of a new light beam that we had discovered. Only later, I realised that she asked her questions in a rather cunning way. At first I said that there were no real applications, it was just a fun thing to do. But, then she phrased it differently and said, 'So, you can't think of any future applications?' Now, if you phrase it like that, it is like a challenge to a scientist, because, of course I can dream up some applications. And then, the article said that Andrew Forbes made a discovery that could cure cancer. So, you have to be very careful of what you say.

5.2.10.6. Risk protection and insurance

"You have to communicate in a way that minimises risk," said Amanda Gouws, "but risk should not stop you from doing it." Being aware of the potential risks of public communication, visible scientists advised certain cautions that scientists should keep in mind when they communicate in public.

> **Sheryl Hendriks**: I'm extremely cautious about what I say in public. I focus on the work we do and the evidence we generate; not my opinion. I don't criticise the government or others via public media.

> **Nox Makunga**: You need to be aware of the risks and dangers when you communicate in public. And, you need to be responsible when you put information in a public space. On social media, you have to remember that you are an extension of your university and you must be careful so that you don't get yourself into trouble.

Additionally, they indicated that they exercised certain cautions when they engaged in the public sphere in order to protect their own reputations. Usually, they have learned over time to be careful, cautious and guarded when speaking to journalists. They refused to give hasty comments. They separated personal feelings from scholarly opinion, and they learned to cope with negative comments from the public.

> **Amanda Gouws**: When you receive your first hate mail, the important thing is not to fall apart. You have to develop a thick skin.

Berger emphasised the need to prepare well for any public or media event, in order to minimise the chances of incorrect information getting into the press. Like others, he also underlined the value of learning from experience, including learning from mistakes.

> **Lee Berger**: It's all about practice, practice, practice. I have made mistakes, and I have analysed what went right and what went wrong. I talk to colleagues about it. After all, we are scientists – we should be a self-correcting system. Every error is a stepping stone to progress and learning from it improves your future communication efforts.

If they felt it was justified, visible scientists occasionally would decline to comment when approached by the media. In extreme cases, visible scientists reduced or avoided public exposure, as was the case with Noakes.

> **Tim Noakes**: I am much less likely to talk to journalists now than before, because I took such a barrage. I now want to stay out of the media, except social media, that's where I work.

5.2.10.7. Perceived risks: summary

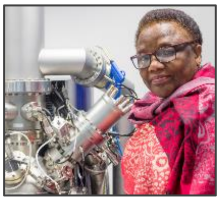
Most participating scientists reported perceiving a level of risk associated with communicating about their research in public. The perceived dangers of public communication were usually linked to their desire to protect their academic reputations, and therefore they feared being misunderstood, misquoted, misinterpreted, getting something wrong or being too outspoken themselves. Some risks were specifically linked to media interactions and social media activity.

Scientists who worked in controversial research fields felt vulnerable to being attacked by the public, but none of the scientists in the current study have ever feared physical attacks on themselves or family members. Learning from experience, including past mistakes, visible scientists developed a range of ways to cope with communication risks and to minimise the chances that future communication efforts would have undesirable outcomes. It can be concluded that participating scientists perceived some level of risk from going public, and that this was informed by their own experiences and their observations of other scientists.

5.3. Contextual factors

Several contextual factors were included in the third cluster of factors explored in the current study. These factors related to the institutional environments where scientists are employed.

5.3.1. The influence of national context




I want to tell the world that Africa is not only about famine and war. We can do science! *(Tebello Nyokong)*

Africa is often seen as the cesspool of the world. I want to help change that. *(Glenda Gray)*

Nationality, linked to regional political and cultural differences around the globe, has been shown to influence researchers' behaviour in the public science arena. In this section, I present and discuss the views of the visible scientists participating in the current study, with a specific emphasis on the influence of the local (South African) context on their involvement in public science communication.

My interview data showed that South African researchers were influenced by local conditions in several ways. First of all, some visible scientists rooted their public visibility in the political history of the country. The ongoing political, economic, educational and health-related problems in the country provide consistent stimuli for public engagement. Furthermore, the natural environment of the country inspire scientists to communicate with external audiences, and their shared interest in the natural environment provide points of contact for scientists to engage with lay audiences.

5.3.1.1. Communication has socio-political roots

For some of visible scientists of South Africa, the roots of their public visibility can be traced back to their experiences during the apartheid[82] years, and their involvement in the anti-apartheid movement in South Africa. This is where they became familiar with public debate and dealing with the media, and they continued to use those skills to speak out about their research. They did not hesitate to refer to their past and current public involvement as 'activism'.

> **Glenda Gray**: My activism started out during apartheid. We protested against things like whites-only hospitals. Activism is not new to me.
>
> **Amanda Gouws**: I have been an activist all my life – out on the streets, especially during the final years of apartheid. I often got into deep trouble because of it. Since then, I've always combined my research with activism. And that is also how I train my students.
>
> **Pumla Gobodo-Madikizela**: When I was a youngster during the 1980s – a very volatile period in our country – I worked with human rights lawyers as a psychologist. I was called as an expert witness to help the courts understand the psychological circumstances that caused people to commit necklace murders. That was my first experience of communicating trauma in public.

[82] During the racially segregated apartheid regime (1948–1994), the political system in South Africa mostly excluded black citizens from economically lucrative scientific, economic and agricultural activities.

Involvement in the public sphere during the transitionary period after the advent of democracy in South Africa continued to make scientists aware of the importance of sharing their insights with broad audiences, locally and internationally.

> **Pumla Gobodo-Madikizela**: When I worked for the Truth and Reconciliation Commission, I had a strong sense that our insights about what happen to people when they are humiliated and degraded, had to be shared. But, I also encountered a different narrative – the story of forgiveness – which I had not seen in the literature anywhere up to that point. Again, I had the urge to convey this to the public – the realisation that forgiveness is possible. The literature focused on the impossibility of forgiveness. And here, in South Africa, we were witnessing the possibility of forgiveness. I really felt a strong urge to write about this for the people of South Africa and the world.[83]

Reflecting on the constrained communication environment during the apartheid years, visible scientists were inspired to share their science with the broad South African society in the new democratic dispensation.

> **Francis Thackeray**: I'm passionate about public communication, because I hope to instil a sense of pride in our South African palaeontological heritage, especially after the cover-up that occurred in the apartheid era.

> **Himla Soodyall**: Given South Africa's history, it is particularly meaningful for people to trace their roots and explore where they belong – not just in terms of their own family, but also in society, nationally, continentally and globally. It is a unifying feeling. I try as best I can to take from my science and marry it with these soft issues, so that people feel that they belong in this tree of life.

In post-apartheid South Africa, there is political support for science communication, and a new freedom to communicate about topics that were previously suppressed. Thackeray provided two examples.

> **Francis Thackeray**: The years between 1994 and 1999 were exciting. The new science ministry supported our initiatives to promote our fossil heritage and that made a huge difference. The South African Mint manufactured a gold coin with the image of Mrs Ples on it. It was the first time ever they put an image of a fossil on a coin and it was an extraordinary success. Also, three world heritage sites were declared in 1999: Sterkfontein, Robben Island and St. Lucia. This was a turning point in the sense that government took note and was proud to promote the message that Africa was the Cradle of Humankind.

Thackeray contrasted this political support for promoting the fossil heritage of South Africa with the situation prior to 1994.

> **Francis Thackeray**: In the 1960s and '70s the teaching of evolution was forbidden in schools, and it was not featured much in the media. But, Bob Brain[84] set up the Genesis 1 and Genesis

[83] Gobodo-Madikizela published in the academic literature, but also wrote a popular book on the topic of the apartheid atrocity, trauma and forgiveness (e.g. Gobodo-Madikizela, 2002; 2003).

[84] Bob Brain, a renowned South African palaeontologist, served as director of the Transvaal Museum for 23 years, from 1968 to 1991.

2 exhibition halls at the Transvaal Museum and it was a huge success, visited by large numbers of school children. It did not mention evolution, but it showed evolutionary trees. Pre-1994, we put a replica of the Mrs Ples[85] fossil on display – depicted with a black skin, and as a human relative, if not a human ancestor. The politicians and the Dutch Reformed Church took exception and eventually that exhibition had to be taken down. After 1994 – with political support – it was a completely different story. I proudly put the exhibition back together with a new model of Mrs Ples, with life-like eyes and hair.

Thackeray also contrasted the objections from leaders in the Dutch Reformed Church (before 1994) with the support from Archbishop Desmond Tutu (after 1994).

Francis Thackeray: When Desmond Tutu went around the Sterkfontein caves with me, he was most impressed. He certainly appreciated evolution and religion, and could reconcile the two. And, when he signed his autobiography for me he wrote: 'Dear Francis, Thank you for your holy work,' signed Desmond Tutu.

However, events and controversies that occurred in post-apartheid South Africa continue to provide scientists with an impetus for going public. In particular, the conflict around Aids denialism between the government, civil society and the medical profession,[86] which peaked during 2000, compelled scientists to respond publicly.

Glenda Gray: If someone says HIV does not cause Aids, and you have a hospital full of dying babies, how can you not speak out?

Salim Abdool-Karim: I was quietly working on my Aids research at the MRC, but when President Thabo Mbeki announced his denialist position, I could not stay quiet. We had to convey the scientific viewpoint in a way that people could understand – clearly and succinctly. If we did not challenge Mbeki's views, how would people be able to make sound judgements?

Bavesh Kana: When we had a government that questioned the association between HIV infection and Aids, I remember asking myself, 'How do we make these messages clear so that there is no room for confusion?' How do we make it clear to policymakers?

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[85] For more on the Mrs Ples fossil, see http://www.southafrica.net/za/en/articles/entry/article-southafrica.net-mrs-ples.

[86] During this time, then South African President Thabo Mbeki questioned the science of Aids and the existence of a virus that caused this disease (Schneider & Fassin, 2002; Fassin & Schneider, 2003; Mbali, 2004). Mbeki's views and unequivocal support for dissident scientists caused an international stir and met with local opposition from the scientific community. The Durban Declaration, launched at the International Aids Conference in July 2000, contained the signatures of more than 5 000 scientists who supported the mainstream scientific view that HIV existed and caused Aids. During this time, the health minister, Dr Mantombazana Tshabalala-Msimang, not only characterised anti-retroviral treatment as toxic, but also widely promoted a variety of untested alternative therapies via the media (Nattrass, 2007). According to a study from the Harvard School of Public Health, it is estimated that the delay in implementing the antiretroviral programme in South Africa during Mbeki's presidency led to the death of more than 330 000 people, while about 35 000 HIV-positive babies were born during this period (Chigwedere, Seage, Gruskin, Lee & Essex, 2008). During this period, there were allegations in the media about medical doctors in the public sector who were penalised if they criticised the government's failure to provide antiretrovirals to HIV+ patients (Joubert, 2007).

More recently, political unrest in the higher education sector, including calls for decolonialising of the higher education curriculum, has given scientists cause to reflect on the public image of science in the country.

> **Anthony Turton**: Science scepticism came into South Africa, and was deeply manifested, when Thabo Mbeki became an Aids denialist. It continues now with calls for decolonised higher education. It is essentially the same debate. It is a clash of cultural values. There is a belief in oral histories and cultural values, versus a completely different perceived alien Western system.

Visible scientists were furthermore driven by socio-political challenges in South Africa to make science more accessible and meaningful within the broad South African society.

> **Mary Scholes**: We have a very unequal society. That is an important driver for scientists to give something back to society.

> **Anthony Turton**: Science must play an important role in determining many of the complex policy decisions in our young democracy. Science must serve society. As scientists, we need to figure out how to make science important and significant in the new South Africa.

> **Hamsa Venkatakrishnan**: In South Africa, access to education is a real issue. For academics concerned with issues around equity and access, it means stepping out of our comfort zones.

> **Anusuya Chinsamy-Turan**: In South Africa – with first and third world elements – it is really important that we spread the word about the possibilities of the diversity of careers in science.

> **Glenda Gray**: Being the president of the MRC, I am a public figure promoting medical science. And, I also do it so that women in Africa can aspire to be scientists, and to change the way women in Africa (and Africans in general) are viewed.

However, in the current political climate, participating scientists also perceived some barriers in terms of achieving policy input based on scientific research.

> **Bob Scholes**: Because of our history, we currently don't have a government which naturally turns to science for solutions. Our leaders come from political backgrounds and instinctively look for political solutions. So, it is a big challenge for South African scientists to develop trust relationships with politicians. We have to show that science is not a threat, but a resource to be used. It is a slow process, but it is work in progress.

> **Anthony Turton**: In South Africa, we have a particular challenge with science because in many cases our political elites are the product of a very flawed educational system and many of them – not all – did not receive good education. As a result, people who barely did science at school now manage government departments dependent on scientific expertise. They roll out programmes that are politically necessary, but none of them informed by science, and all of them have major environmental implications.

Some of the participating scientists also indicated an awareness that some topics were politically sensitive, and that could cause them to avoid public communication about these topics.

> **Linda Richter**: There are some topics in South Africa that I would feel uneasy about if I had to speak about it in public. These are unpopular causes that meet with political disapproval, especially when you have findings that may clash with human rights.

While there was no evidence (from the current study) that the South African government sensors scientific findings (as was demonstrated for Zimbabwe by Ndlovu *et al*., 2016), the comment by Richter showed that scientists were mindful of the risks of talking about potentially sensitive topics.

5.3.1.2. Communication driven by burden of disease

Another key motivating factor that inspired researchers, particularly those working in health-related fields, was the prevalence of diseases in South Africa, especially HIV/Aids and related diseases.[87] Confronted by the human cost of disease, researchers were inspired to make the latest research information accessible to improve people's lives, as well as to combat misinformation. They perceived that the public was keenly interested to know more about health-research findings.

> **Glenda Gray**: We focus on diseases that affect South Africans. We have the biggest TB burden in the world. We have high HIV rates. So, people want to know about that.

> **Tim Noakes**: We are drowning in chronic disease. Scientists must speak up about that.

> **Bavesh Kana**: TB in South Africa is a public tragedy that you cannot imagine. In South Africa, more people die of TB than anything else, even when we have a vaccine and we have a treatment regime. That is shameful, right? That is why I refuse to go down in history as part of a society where all these people died of TB, but I did not try to communicate about the issue. I have to keep on communicating, because the more we have messages about TB – and the care patients need – in the public space, the more it will occupy people's minds and the more they will be prone to the human kindness that the disease needs so much. So that is why I do it. I feel like, eventually, we can shift the tide on this disease.

> **Linda-Gail Bekker**: My public profile is linked to importance of my field of research, and the fact that – at the time when my career was unfolding – we were at the height of the HIV epidemic and at the height of our TB epidemic, and people wanted to hear more about it.

The prevalence of some diseases in South Africa, combined with societal issues, such as inequality, low education levels and poverty, cause scientists to perceive several pressing communication challenges in the local context.

> **Salim Abdool-Karim**: People are desperate. And people want to believe in traditional medicine in a way that is probably not true in other settings. Some of my patients come in

[87] According to Statistic South Africa (Stats SA) (2016), the estimated overall HIV prevalence rate amongst the South African population is 12.7%. The total number of people living with HIV is estimated at approximately 7 million people. For adults aged 15–49 years, an estimated 18.9% of the population is HIV positive.

> with a concoction called 'uBhejane'.[88] We investigated and found that it came from a truck driver who was fired from his job, and was now filling bottles with coloured water and selling it as HIV medication. And, that kind of thing I have to expose, with the help of the media.
>
> **Bavesh Kana**: I was speaking at a World TB event last year when a journalist asked me, how I could speak to people about taking their drugs every day if they don't have food to eat. I was not prepared for that question. So, we have to understand that many TB patients live in abject poverty. But, I also tried to explain that poverty makes the disease worse. And, we have to appeal to communities to support individuals in such dire situations.

This comment by Kana about the challenges of talking to TB patients about medication when some of them did not have food to eat, was a reminder of the communication challenges faced by scientists who engaged with very poor communities, as has been outlined by Lewenstein *et al*. (2002). Similarly, the experience of Abdool-Karim of the need to combat myths about Aids cures was in line with reflections by Manzini (2003) about how myths and superstitions cause social problems in South Africa and complicate the communication of science with affected communities. My findings furthermore validate earlier scholarly opinions about the challenges of communicating science in unequal societies and multi-cultural settings (Lewenstein *et al*., 2002; Manzini, 2003), but also reminds of earlier findings that scientists are particularly motivated towards public communication when they believe that a lack of public knowledge about science could be harmful (Besley *et al*., 2013) and that scientists often prioritise communication designed to educate the public and defend science from misinformation (Dudo & Besley, 2016).

The present-day, tumultuous political climate and pressing social problems in South Africa provide further stimulus for scientists' interest to engage with the broad society.

> **Amanda Gouws**: Political science is a hot topic here in South Africa. I regularly visit Sweden for work, but find that I'm bored with the political scene within a week. Here, there is a lot more happening and a lot more to discuss.
>
> **Glenda Gray**: I could only be a doctor here. I understand our diseases. I feel passionate about finding solutions here, and making these solutions accessible to fellow South Africans. It would be bland to work in a country where these compelling issues are absent.

The findings (presented above) are in line with what literature shows about the regional nature and cultural variances that characterise science communication, as proposed by Bucchi and Trench (2014), as well as Medin and Bang (2014).

5.3.1.3. Communication inspired by the natural environment

Lastly, visible scientists participating in the study drew inspiration from the natural environment and heritage of the country (environment, biodiversity, etc.) and its unique natural history. They saw it as a unique place to do research, which offered unparalleled opportunities for sharing their work

[88] This herbal mixture was reportedly also promoted by provincial health officials in KwaZulu-Natal (Cullinan, 2006). This was linked to "a deep-rooted suspicion of 'white' medicine, and the reliance on unreliable, anecdotal evidence that the tonics work to cure HIV" (Batts, 2006).

with the broader community. They also perceived that the public was particularly interested in science that was linked to the South African natural history and environment.

> **Dave Pepler**: Our African context is unique for doing science. Our ecologists and engineers work in the best open-air laboratory in the world. We have some of the richest biodiversity on the planet. If you want to know anything about life, this is the place to be.
>
> **Don Cowan**: We have an exciting national environment for science and for communicating science.
>
> **Bob Scholes**: Our beautiful environment and extensive natural history creates connections with society.
>
> **Bruce Rubidge**: I grew up with fossils in my backyard, and it has been my life-long ambition to share my passion for our fossil heritage with other people. We have made a huge contribution to understanding the origins of life, because of the fossil resources of this country. It is something to be celebrated and to be proud of.
>
> **Jill Farrant**: We have the most beautiful flora in the world and a lot of it. The resurrection plants I work with are uniquely South African.
>
> **Marcus Byrne**: South Africans are really interested in wildlife and the wilderness. If you talk about these topics, the response is fantastic.

5.3.1.4. Influence of the national context: summary

Participating scientists perceived South Africa as a unique place to do and communicate science. This perception was rooted in the history, heritage and diversity of the country, in the natural and human contexts. Specific events in South African history have piqued their awareness of the need for public science engagement, while current events and societal challenges (inequality, poverty and disease) sustained their view that scientists must be visible in the public sphere. Furthermore, factors that are unique to the South African context influenced the way these scientists viewed public science communication and affected their participation in these activities. These factors were related to the exceptional natural environment and natural history of South Africa, but also to societal challenges, such as poverty and disease.

Participating scientists' perceptions of the constraints on public science communication before 1994 are in contrast with the more supportive conditions in the democratic South Africa. Several participating scientists perceived that, in the new, democratic dispensation in South Africa, political support for public science communication makes it much easier to raise awareness about certain scientific topics, with a small number of scientists experiencing barriers in engaging with policymakers in the current government. This confirmed that political support and leadership made a crucial difference in scientists' ability to engage with society.

5.3.2. The influence of the institutional environment


My work in the public media is important, and it should mean something in terms of the recognition I get in the university. *(Amanda Gouws)*

If there are rules about who I'm allowed to speak to, I'm unaware of them. But, I'm also a rule-breaker, so they would not stop me. *(Linda-Gail Bekker)*

In this section, I review the effect of institutional factors on whether or not scientists participate in public science communication, based on evidence from the current study.

5.3.2.1. Institutional communication culture

"By now it should be clear to any university in the world that public communication has become a critical part of modern academic life," Berger said about the place of public communication in the institutional culture at universities. Despite his view of the centrality of public communication in academic institutions, most of the researchers I interviewed were more or less neutral about how they perceived the culture at the institutions where they were working at the time of this research in terms of public science communication: they did not perceive it to be particularly encouraging, but also not specifically restrictive. While they felt that their efforts were generally appreciated, many of them commented on the lack of any official recognition for the time and effort spent on public engagement.

In some cases, scientists working at the same university experienced the institutional culture rather differently, depending on their own situation. For example, it is no secret that senior academics at the University of Cape Town distanced themselves publicly (by writing an open letter to a local newspaper) from the views of Tim Noakes. He was, understandably, negative about the institutional culture, describing it as "atrocious", adding that he had "nothing positive to say". By contrast, Chibale had a very different perception of the communication culture at the same university.

> **Kelly Chibale**: I am grateful that I am at a university that encourages public communication, not only within the university, but also to the outside.

Some researchers were aware that their universities encouraged community engagement, but were uncertain whether their public communication work would count in this regard. For example, Nyokong said the following about how she perceived the communication culture at Rhodes University:

> **Tebello Nyokong**: I'm not sure, we don't talk about it. We have awards for community engagement, but is my media work really community engagement? I don't think so.

Further comments from the interviewees illustrated how the organisational communication culture was shaped by the example set by the leadership.

> **Sheryl Hendriks**: When the marketing department send out tweets, they are faceless. But when our vice-chancellor Professor Cheryl de la Rey posts online videos addressing students and staff, her face and voice is there and it is so much more powerful.

In line with the findings from the current study, the science communication literature confirms that organisational culture and infrastructure have a direct bearing on the public visibility of researchers (Lunsford *et al*., 2006; Van der Auweraert, 2008; Bauer & Jensen, 2011; Searle, 2011; Besley *et al*., 2013; Dudo, 2013; Entradas & Bauer, 2016). In particular, the literature accentuates the pivotal role of institutional policy in terms of encouraging or constraining public communication activities of individual researchers. "If no one at the top of an institution regards communication as serious, then it will always be a fringe activity," states a Wellcome Trust report (MORI, 2001:7). Similarly, findings by Van der Auweraert (2008) highlight the role of universities to normalise public communication activities via their policies and support structures.

5.3.2.2. Institutional communication policies

"Not as far as I know" was the most frequent response when I asked interviewees whether they were required to get approval from anyone before speaking to journalists or other external audiences. "Maybe there is a policy, but I haven't seen it," Makunga replied. "If there is a policy, it is not active," was the response from Berger.

Correspondingly, earlier studies found that researchers are often uncertain about institutional policies regarding external science communication, and that uncertainty may result in a general reluctance to become involved (Gascoigne & Metcalfe, 1997; Holland, 1999; Andrews *et al.,* 2005). Also, when institutions fail to recognise science-in-society activities as an integral part of the research profession, this hampers public engagement (Casini & Neresini, 2012).

Hendriks was the only researcher who recently engaged with an official communication policy at the university, in this case the policy regarding social media use at the University of Pretoria. Her comments illustrated that an enabling policy, and researchers' awareness of such a policy, could serve to encourage, rather than inhibit, public communication activities.

> **Sheryl Hendriks**: We put this policy on the table during a recent workshop and the researchers were terrified at first. They were expecting a set of rules saying 'thou shalt not do this and that'. But, they were surprised to see how enabling and helpful the policy was. They were too scared to use Twitter before to communicate their science, but now that they have seen the official policy, they know that they are actually encouraged to use the Tuks[89] Twitter handle when tweeting about their science.

Despite uncertainty about institutional science communication policy, scientists were generally aware that their universities had a code of conduct for staff which prohibited them from doing anything that would bring the organisation into disrepute. "We encourage individuals not to

[89] 'Tuks' is an informal name for the University of Pretoria.

comment on official university policy matters, and to rather refer those issues to the university spokesperson," said Abdool-Karim.

> **Cathi Albertyn**: If you go too far and say things that are sexist or homophobic, the university would rein you in.
>
> **Don Cowan**: If I did something really stupid in a public space, I am sure that I will get a call from the dean or vice-chancellor at some point.
>
> **Bavesh Kana**: There is nothing that stops me from speaking to journalists, but I do stand accountable if I bring the university's name into disrepute; that has been made clear to me.

"There are absolutely no restrictions on talking to the outside world about your field of expertise," Mary Scholes said. With one exception, interviewees were not aware of any organisational policy that restricted their communication with external audiences as far as their research or scholarly opinion was concerned. Several referred to the principle of academic freedom that safeguarded their right to speak freely about their work and views. Soodyall, who held a dual appointment at the University of the Witwatersrand (Wits) and the National Health Laboratory Service (NHLS) was the exception. While she described the communication culture at Wits as encouraging and supportive, the situation at NHLS was very different.

> **Himla Soodyall**: If an NHLS employee wants to engage with the media, there is a form you have to fill in that has to be endorsed by the CEO (chief executive officer). So, if you were to call me as a journalist, I could not give you an answer without clearing that route first. They made this rule after the NHLS went through some challenges and people spoke to the media, resulting in bad publicity. Now, the CEO wants to control what goes out there.

She went on to explain why she experienced this restriction as frustrating and limiting.

> **Himla Soodyall**: A while ago someone from the BBC wanted to conduct an interview with me, but it took forever to get the approval, so the media team left without interviewing me, and we missed out on that important opportunity. It feels like censorship in some way.

5.3.2.3. Relationships with institutional communicators

Institutional communicators play a key role in encouraging or inhibiting the public communication efforts of individual scientists, and researchers may feel frustrated and irritated when they experience that institutional communicators place excessive demands on their time, do not provide the support they need, or filter the topics that the university presents to the media (Van der Auweraert, 2008).

The researchers that I interviewed had very different experiences of the type and quality of communication support offered by institutional communication staff, even within the same university. Some of the researchers experienced varied levels of support across a number of organisations with which they interacted. Other scientists were generally despondent about the institutional communication support they received, referring to their communication offices as "useless" and "slow", while yet others praised the expertise and services they received from institutional communicators. A recurring complaint related to the perceived inability of communication staff to write good press releases, and to adapt or target press releases effectively at different audiences.

> **Don Cowan**: Occasionally, the university publicity vehicle churns its way into action and produces a press release, which I generally re-write before it gets sent out. They tend to be reactive rather than pro-active, but it is better than nothing at all.
>
> **Sheryl Hendriks**: Our marketing office is amazing. Isabel and her team are very supportive. They have a limited team and budget, but they are very good at referring journalists to us.
>
> **Bob Scholes**: Wits is exceptionally good – very professional, very helpful, overall great. My experiences at the CSIR are very mixed – some communicators are wonderful, some have absolutely no idea whatsoever. My experience with government communicators has been just atrocious.

Most interviewees agreed that an institutional media office played a key role in helping scientists to interact with the outside world, in particular with the mass media.

> **Nox Makunga**: I don't think I would have as much visibility without them, actually. They make the connections. They make it much easier for me.
>
> **Bavesh Kana**: It really helps to have someone who has the media contacts and can do the legwork, and Wits is good with this.
>
> **Kelly Chibale**: It is vital to work with a communication specialist who is absolutely professional and knows how to deal with the media and who can guide you on how to pitch your messages. That is something we, as scientists, don't know – we are not trained for that.
>
> **Linda Richter**: To do a proper media blast, you need specialists with global media contacts.

"We are a well-oiled machine when it comes to this stuff," Berger said about his relationship with the communication office at Wits.

A good relationship between individual scientists and senior institutional communicators was key for those scientists who wanted to maximise opportunities for external communication. Furthermore, it seemed as if those researchers who knew the institutional communicators on a first-name basis and who demonstrated a willingness to engage were likely to get the lion's share of communication opportunities. "Martin Viljoen knows he can phone me anytime if he needs someone to speak to the media," Amanda Gouws said. It clearly also made a difference when researchers understood how the media worked and what communication professionals needed from them in order to gain publicity for research. "We work well in advance when we have a paper coming out, lining up the documentation and visuals," Rubidge said about his collaboration with the Wits media office. "We know what they want, so we give them lots of warning."

When an individual science communication professional gained the trust and respect of top researchers, it seemed to have a significant influence on how the researchers viewed their relationship with this communication expert. More than half of the visible scientists at Wits highlighted the exceptional role of Shirona Patel and her team in the university communication office, while several also accentuated the need for a central media office staffed by professional communicators.

> **Francis Thackeray**: Shirona Patel and her staff have been doing extraordinary things to get our discoveries on radio and television, locally and worldwide. I'm deeply impressed by what they do and deeply indebted to them. This kind of central media office is absolutely essential.

> **Linda Richter**: Shirona and her team are very helpful, always looking for stories to communicate. It is not something we as researchers can do on our own. You need a communication person for that kind of work.

> **Marcus Byrne**: The people in our press office have done fantastic things for me. Whenever we have a story to promote, they have been just brilliant. I am quite spoilt by my relationship with them.

The importance of institutional support (with specific emphasis on PR expertise) in terms of enabling scientists to engage with external audiences is well documented (Marcinkowski *et al*., 2014; Dudo, 2015; Lo & Peters, 2015). Frequently, a lack of support, and a lack of awareness about communication opportunities, emerge as key barriers limiting scientists' engagement with external audiences (Andrews *et al*. 2005; Salguero-Gomez, Whiteside, Talbot & Laurance, 2009; Kuehne *et al*., 2014). Bob Scholes emphasised, however, that scientists themselves had to remain central in the process of communicating science.

> **Bob Scholes**: When you communicate about something which is in a subject domain, your very best communicator is the domain expert. The role of the communication professional is to create the communication opportunities, to make the connections and to set up the interviews. They should also guide the scientist through the process, and make sure they don't get manhandled – you know, protect them from the rough and tumble of media attention.

The findings of my study corresponded well with a similar study by Van der Auweraert (2008). Van der Auweraert says that scientists would value communication support from professional science communicators who were pro-active, creative and well-connected in the media world. These support services have to be legitimised by institutional leadership, policies and incentives that would recognise and support these activities.

5.3.2.4. Barriers that deter science communication

The skill barrier prevents you from making a start, but the time barrier stays. *(Don Cowan)*

If you think it over, the most important barrier is time, right? *(Amanda Gouws)*

A lack of time and a lack of recognition emerged as the two main barriers that limited the efforts of visible scientists in terms of engaging with public audiences. In Figure 5.5, the weight of the different barriers, as perceived by the visible scientists in the current study, is depicted. The skills barriers that visible scientists perceived were mostly related to mass and social media.

Figure 5.5: Science communication barriers perceived by visible scientists

The communication barriers that visible scientists in the current study experienced were in line with barriers identified in earlier studies, with time constraints frequently emerging as the most pressing constraints deterring scientists from public engagement (MORI, 2001; Andrews *et al*., 2005; Mathews *et al*., 2005; The Royal Society, 2006; European Commission, 2007; Poliakoff & Webb, 2007;Van der Auweraert, 2008; Kreimer *et al*., 2011; Searle, 2011; Allgaier *et al.,* 2013b; Smith *et al*., 2013; France *et al*., 2015; TNS-BMRB, 2015; McCallie *et al*., 2016; Namihira-Geurrero, 2016).

In this study, several interviewees indicated that they made time for public engagement despite their busy schedules and extensive academic responsibilities.

> **Himla Soodyall**: I do have to teach; I do have to do research; I do have training, administrative and committee responsibilities. These are all things that come with the territory, and all of it goes well beyond a day job. So, my public engagement happens after hours and over weekends.

> **Kelly Chibale**: There is time for everything if you want to do it. If you think it is important, you can fit it in. It is a matter of priorities.

"In terms of career progression or funding, you would never know whether a public profile counted for or against you." Mary Scholes explained the uncertainty that she perceived about the outcome of her public communication efforts. Several other interviewees verbalised how they felt about the lack of recognition for the public communication efforts.

> **Tolullah Oni**: It takes up a lot of time and we have to acknowledge that. There is also the perverse side that the time that it takes is not necessarily acknowledged and appreciated. It is a kind of acknowledgement that is necessary, especially amongst scientists, because it is an additional load that communicating scientists have to carry.

Amanda Gouws: I was unhappy because it felt to me that no recognition was given to the time that I take to communicate with the media. I could go and play golf or I could have gone to the movies, but I don't, because I invest the time in public communication. And all I expect is that recognition of the time that goes into it.

Sheryl Hendriks: We are busy with performance appraisals now and there is just zero place to report public communication. It is very frustrating.

Linda-Gail Bekker: Public communication should not happen at the expense of academic publication, but it must count in addition to academic work. It is very important, and it is not necessarily regarded when it comes to promotions and other career progression.

Anusuya Chinsamy-Turan: What happens at universities is that you mostly get credit for academic publications, for teaching, and for academic leadership. But, social engagement counts for very little.

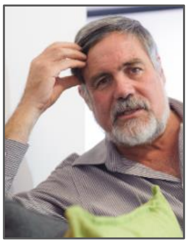
There is widespread consensus in science communication literature that the lack of institutional recognition and reward inhibits scientists' involvement in public outreach activities (Treise & Weigold, 2002; Mathews *et al*., 2005; Vetenskap & Allmänhet, 2007; Jensen *et al*., 2008; Martín-Sempere *et al*., 2008; Peters *et al*., 2008b; Burchell *et al*., 2009; Wigren-Kristoferson, 2011; Casini & Neresini, 2012; Ecklund *et al*., 2012; Illingworth & Roop, 2015). Van der Auweraert (2008) emphasises researchers' need for recognition and motivation towards public communication coming from institutional policy and reward systems.

Other obstacles that were mentioned related to funding and language barriers.

Linda-Gail Bekker: There is often no line item for communication in a budget … it is often neglected when it comes to funding, and it should never be neglected. So, funding becomes a huge barrier. It costs a lot of money to get help from a professional science writer. They are skilled at what they do and they have a right to charge, but it is expensive. So, we often end up doing our own kind of homemade job, but it is hard, because academic writing and popular writing are two very different things, and many scientists are reluctant to make that shift. So, we really need help from professional science writers.

Tebello Nyokong: I am Sotho-speaking, but it is too difficult to communicate science in my own language. I can't, we simply don't have the vocabulary for science.

5.3.2.5. Incentives that (could) encourage public science communication



There is a role for recognition and rewards for public science communication. Even if people like me say it does not matter – actually, it really does. It feels really good to get the recognition from your peers and colleagues. *(Bob Scholes)*

"We should recognise and reward public science communication more formally," Tinyiko Maluleke replied when I asked him which incentives he would propose to encourage researchers' involvement. Most visible scientists agreed with this view.

Bob Scholes: You don't have to push people, just recognise the effort. Just make sure people know that their public communication work will be taken into consideration when it comes to performance evaluations.

Nox Makunga: The way academics are rewarded has to change in order to take science communication into account … it may not be today, but I think that change is on its way.

Andrew Forbes: I think public communication should be part of the metrics that is used to judge scientists. There must be an official way to report on what I've done to communicate with funders and the public.

Some interviewees agreed that public communication should count when it came to career recognition and funding, but they were hesitant about how to introduce it in the performance and funding appraisals in academic environments. "Academics are already stretched between multiple demands, so one would have to be very careful how you introduce another thing we have to do," said Cathi Albertyn.

In some organisations, efforts to recognise public communication efforts were already taking shape, as Gray explained, and interviewees were generally aware of increased expectations from local and international funders in this regard.

Glenda Gray: Last year, we have introduced a formal indicator in all job descriptions at the MRC called 'A Good MRC Citizen' and spending time on explaining your science to the community would most certainly count for that. It was specifically created to recognise the non-academic side of science communication. We will develop that indicator further once we see what people regard as good MRC citizenship.

Bavesh Kana: Expectations from the NRF and MRC are becoming stronger about how we are going to take our research back to the communities. Internationally, for our NIH grant, they want to know how we are going to disseminate the knowledge.

Kelly Chibale: Today, we see a change at UCT. Instead of focusing on teaching, research and administration only, they have brought in another category called 'social responsiveness'. It includes the things that you do to give back to society, for example to go and speak at a school. So, already in the current system there is recognition at UCT. I do agree that this is an important area. I cannot overemphasis how important this is. There are many implications, positive implications, not only on people deciding to follow careers in science, but also on influencing our leaders in terms of where the money should go to fund what.

Don Cowan: While there is very little expectation about public science communication in South Africa, my colleagues in the UK and New Zealand all have to write substantial sections on how they are going to promote the research in the public space when they apply for funding. But, things are now also changing in South Africa. In the 2017 round of NRF applications, they are now, for the first time, asking applicants to plan for communication of the research.

In line with the perceptions of visible scientists in the current study, there is widespread recognition that institutions increasingly expect of their research staff to make their research more publicly visible than before, and that they are investing in support structures and services to facilitate this

(Neresini & Bucchi, 2011; Entradas & Bauer, 2016). However, some studies continue to highlight a general lack of incentives that would encourage scientists to engage with public audiences (Greenwood & Riordian, 2001; MORI, 2001; Andrews *et al*., 2005; Kim & Fortner, 2008; Besley & Nisbet, 2013; Kreimer *et al*., 2011; Searle, 2011; Ecklund *et al*., 2012; Smith *et al*., 2013; France *et al*., 2015; McCann *et al*., 2015; TNS-BMRB, 2015; Namihira-Geurrero, 2016).

Some scientists interviewed for the current study felt strongly that public communication deserved more recognition and reward. Chinsamy-Turan, for example, was in favour of direct incentives.

> **Anusuya Chinsamy-Turan**: To grow and nurture a culture of public communication, you definitely need to incentivise it. I would create grants for communication and more platforms to recognise people's contributions.

However, not all interviewees shared this view. Byrne, for instance, was in two minds about whether scientists deserved special recognition for going the extra mile to engage with the public, while Abdool-Karim felt strongly that public science communication did not warrant any official institutional recognition or reward.

> **Marcus Byrne**: It is time-consuming to engage with the public, and maybe scientists do deserve some recognition for doing that. Even giving a talk to the Horticultural Society where there are six people and a dog and everyone is over 70 takes time – the whole evening gets blown away. But I will prepare my talk the night before and I do put in a lot of effort, because I do think that we have to get it right. Do I deserve anything extra for that? It is a difficult one. I suspect not, because it is my choice to do that.

> **Salim Abdool-Karim**: Our job is to do good science and to communicate it. It is part and parcel of the job. I don't see it as anything special.

However, it was clear that most scientists appreciated recognition for their public communication efforts, even outside the official performance appraisal process. Several scientists mentioned how important it was for senior management to notice and acknowledge public communication efforts, even if these acknowledgements were done informally.

> **Marcus Byrne**: When you hit the media and you get feedback via your institution – a mention by the dean or in a university publication – it gives me a buzz!

> **Kelly Chibale**: I don't think money is always the solution. Often it is simply to be recognised. And, a communication prize would be a good way to incentivise people.

Previous studies recognised that many scientists desire institutional recognition and that they pursue public visibility in order to achieve this (Marcinkowski & Kohring, 2014).

While some interviewees were not in favour of the idea of incentivising public communication via an institutional award or prize, others thought it would be an excellent idea. Byrne, who had previously won an award from the NRF in recognition of his public engagement work, said that he was "absolutely delighted" to have received this award.

In terms of putting a part of research funding aside for public communication, Bob Scholes suggested that this should be a guideline rather than obligation. "If you set it up as a ring-fenced hard obligation, people will not necessarily spend it wisely," he said. "But, scientists must know that it is OK to spend money on communication and that their efforts will be recognised – absolutely."

When I asked the visible scientists how they would use the money if they were given a separate budget for public communication, they came up with interesting and creative possibilities.

> **Marcus Byrne**: I would make short videos – little vignettes of beetles doing something really cool, or an invasive plant getting smashed by a particular bio-control agent.
>
> **Bavesh Kana**: I would appoint facilitators to put our top scientists in schools, shopping centres, factories and mines – in meeting places where they can engage people in conversations and where ordinary people can ask questions.
>
> **Nox Makunga**: I could do amazing things if I had access to a videographer and illustrator to make our own YouTube videos about South Africa's medicinal plants.
>
> **Bob Scholes**: I'm a huge believer in infographics as a powerful communication medium. Working with people who create these have been a real eye-opener for me, and a learning experience. I would love to do more with infographics.
>
> **Andrew Forbes**: I would like to create interactive, online versions of our science stories.
>
> **Linda-Gail Bekker**: I would love to do more with using drama to communicate science, and getting better with visual aids such as YouTube videos. A 90-second video about your work can be more powerful than 20 pages of motivation when you are writing a grant.

5.3.2.6. Support services that (could) encourage communication

"We have an excellent communication model that really works well," Kelly Chibale said when I asked him about the kind of institutional services and support that he values in terms of public science engagement.

> **Kelly Chibale**: There is the central UCT communication and marketing department. There is a dedicated person in the research office that seeks out science stories, and then we also have someone in the science faculty who pro-actively encourages science communication. That makes all the difference. No one here has an excuse for not communicating properly.

The role of institutional research offices in aiding public science engagement is highlighted for the South African context by Botha and Hunter-Hüsselman (2016). When I asked participating scientists about the kind of institutional support service that would make the biggest difference in terms of supporting their public communication efforts, many of them emphasised the need for a pro-active approach on the part of their universities to identify and promote science news and topics for public engagement.

> **Anusuya Chinsamy-Turan**: The people in the central media office are stretched, so they are not actively looking for science stories. They never ask me, I have to go to them with ideas for press releases. Now, we have a person in the research office who is filling that gap. I like the approach of the Fitzpatrick Institute for African Ornithology in our department that has

a dedicated person who writes press releases and popular articles to make sure that all the academic articles get wider exposure.

Amanda Gouws: I would create opportunities for younger scholars to write popular stories, to conquer that fear of doing it for the first time and to see the impact for themselves.

Francis Thackeray: Here at Wits we have people who actively go out to find out what staff are doing, and encourage scientists to tell their stories.

Cathi Albertyn: I like writing, but I'm bad at offering it. But, if someone asked me for an op-ed piece, I would do it. So, you need to pro-actively identify and invite people to write and solicit them for media interviews. I would also give them some media training.

Marcus Byrne: Someone who goes around and prise the stories out of scientists: I suspect that is the best way to do it. You actually need to have a dedicated individual who literally has to go door-to-door and dig for the stories. Because scientists sometimes sit on amazing stories and they don't know it, or they are just too busy. And you just need somebody to come along and show a little bit of interest and then it pops the whole thing wide open.

Linda-Gail Bekker: Communication is not always front-of-mind for researchers. So, it would be great if institutional communicators could help us focus more on disseminating our research results, not only the hard science news.

Scientists' preference for getting help from professional communicators, and the stimulating effect of such communication professionals on scientists' public communication activities, have been demonstrated in several studies (e.g. Peters, 2008; Escutia, 2012).

5.3.2.7. Institutional environment: summary

The fact that more than half of the visible scientists identified for the current study were employed at just four universities suggested a supportive institutional culture at these universities in terms of public science communication. As pointed out by Baram-Tsabari and Lewenstein (2012), scientists are best able to learn the discourse of public engagement in socio-cultural environments that value such practices.

The findings of this study, and in particular researchers' comments about the communication support they experience at Wits and the University of Cape Town, further strengthened this finding. For many interviewees, the help that they received from institutional communication offices played a significant role in their efforts to achieve public visibility for their work, but some complained about slow or inefficient communication support. Many interviewees highlighted the need for more pro-active communication support where professional communicators help scientists to identify and communicate newsworthy research. In terms of communication barriers, a lack of time remained the most important constraint, while scientists also referred to obstacles such as a lack of recognition, a lack of funding and language barriers. Most participating scientists were in favour of more incentives, such as prizes, official recognition and/or funding, to encourage science communication initiatives.

5.3.3. The influence of evaluation practices

I Google my name sometimes to see what sort of electronic profile I have. *(Cathi Albertyn)*

In this section, I outline my findings about how visible scientists responded to evaluation as one of the factors that was expected to influence their public science communication activities.

The question "How do you know that the money and time you spent on public science engagement was a good investment?" was one of the challenging issues in my interviews with 30 visible scientists. "Public communication impact is kind of nebulous and therefore very difficult to measure," Tim Noakes said. "I am not sure who I am reaching, but I wish I knew," Tebello Nyokong replied. Most interviewees admitted candidly that they did not make any effort to monitor or measure their public outreach work, nor did they have any idea how to do it should they wish to make a start. However, most of them saw it as something that could add value, and felt that they would like to evaluate their communication efforts more formally and more effectively than they did at the time.

5.3.3.1. Evaluation would be valuable

Despite the apparent lack of formal evaluation of public science communication and the scarcity of expertise in this regard, all the scientists I spoke to agreed that some form of monitoring and/or evaluation of their public communication efforts would be meaningful and even exceptionally valuable.

> **Jill Farrant**: It would be really nice if somebody could keep track of my media profile. It would be great to have it captured so that I could use it when applying for a grant or when you become eligible for an award. In the year after I won the L'Oréal Award, they kept track of it and let me know that I was featured in 750 popular articles. That was like – wow! It would be wonderful to have that kind of information at your fingertips on a more permanent basis.

> **Kelly Chibale**: We have not really thought about evaluating our communication activities, but that is something we really should do. We could definitely use the evidence in future collaborations.

> **Nox Makunga**: It would really help me to have some kind of evaluation of my public talks and social media impact, because that would guide me in terms of what is working, and what is not.

5.3.3.2. Uncertainty about evaluation methods

Many scientists were uncertain about how they could go about the monitoring and evaluation of their public science communication activities. They perceived it as something "difficult" or even "impossible" to do.

> **Tolullah Oni**: It would be very interesting to evaluate our communication efforts, but it would be very difficult to quantify or to operationalise the outcome variable. Impact is always hard to measure, especially long-term impact.

> **Cathi Albertyn**: I don't really know how to evaluate my communication impact on an individual level. I guess you can see how many people read your work on 'The Conversation', or how many people re-tweet you on Twitter. Maybe it is measurable in some of those ways. There are computer programmes that can measure your media presence, right?
>
> **Anusuya Chinsamy-Turan**: It is really difficult to measure these things. Sometimes you will know about people you have touched, but many times you won't know.
>
> **Don Cowan**: Communicating science is all positive stuff, but it is almost impossible to quantify. So, there is a sense that the feeling that you are doing something of value – no matter how much or how little it is – that is the only reward you are going to get.
>
> **Hamsa Venkatakrishnan**: The academy has become very competitive, in some regrettable ways. So, it will be very difficult to decide what to count in terms of media and social media, and what not, and where to draw the line.

These comments resonated with the scholarly opinion that many scientists see public communication as informal activities performed for the public good that do not warrant formal evaluation (Holliman & Jensen, 2009), and that scientists are often uncertain about what constitutes success in public engagement and which criteria could be used to assess these activities (Grand *et al*., 2015).

Contrasting with the view that meaningful evaluation of public communication would be difficult to achieve, Scholes offered a different perspective.

> **Bob Scholes**: Remember, evaluating the quality of science is also subjective. When science communication is well done, it is clear, it is not ambiguous at all. So, we have to find a way to document that.

5.3.3.3. It is already happening, but does it count?

Some researchers were aware of monitoring and evaluation activities relevant to public science communication that took place at institutional level, and they were mostly positive about these efforts.

> **Salim Abdool-Karim**: Our communication department keeps track of all my media appearances and, given the amount of time it takes, it is extremely useful to have those statistics. The analysis of the content of my media appearances tell me what the most common themes and questions are.
>
> **Cathi Albertyn**: I know the university looks at which academics have the biggest footprint in the media each year, and Adam[90] is really proud of that.

Despite the awareness that public communication efforts were noted at institutional level, none of the interviewees were aware that their universities incorporated these statistics into a formal evaluation system, which could signal that institutions rate public communication as marginally important (Neresini & Pellegrini, 2008). Consequently, interviewees were uncertain about how evaluation data were used and whether it made any difference. These findings resonate with the

[90] Professor Adam Habib was the vice-chancellor of the University of the Witwatersrand at the time of this study.

views of Nhamo (2013) that universities routinely emphasise the important of science engagement and outreach, but that these activities are not taken seriously when it comes to formal job descriptions and performance evaluations, resulting in uncertainty about the professional rewards that scientists could expect from spending time on public engagements (Neresini & Pellegrini, 2008; Liang *et al*., 2014).

> **Mary Scholes**: There are plenty of opportunities to fill in information about public awareness in your annual progress reports to the university or the NRF. There are categories to record the number of people you have reached, etc. Unfortunately the loop is not closed, because nobody reads those reports. I log all my media interviews and public talks, and I submit the information, but it does not actually feed into the system.

Some of the scientists that I interviewed relied on informal feedback from audiences to determine whether their science communication efforts were hitting the mark.

> **Bob Scholes**: It is true that it is hard to evaluate informal engagements with the public. So, I look at things like body language; the questions I get from the audience; comments after the lecture – that kind of feedback tells me whether my talk was on track or not.

However, several interviewees were making an effort to commence with more formal evaluation activities, but remained uncertain about best practice and encountered significant obstacles along the way.

> **Sheryl Hendriks**: We want to evaluate our science communication efforts properly, but it has been a frustrating journey. We have started to explore what we can do with altmetrics, which seems like a useful possibility, but the university is not subscribed. So, we signed up for Google Analytics, but that is not really giving us what we want. For now, we are just tracking things like Twitter followers, Facebook likes, website visits, Newsclip mentions, etc. We keep on asking our researchers to send us the information when they have been in the media, so that we can keep a database of articles, radio interviews and so on. We get stats from 'The Conversation'. At least we are making a start, but it is quite messy.

> **Andrew Forbes**: We try to put a value to media appearance, depending on the space we get in newspapers, and we count the number of hits we get online. We also search for our own material online to see how easy it is to find it.

> **Anusuya Chinsamy-Turan**: For the MOOC[91] I'm currently doing on the past and present extinctions, I decided that I want to have a proper evaluation of how well we do at communicating the science. Are we reaching our goals? It is a big problem that there is literally nowhere to apply for money for that. So, I met with an evaluation expert, and I'm still trying to find funding for the evaluation component.

Berger was one of several researchers who indicated confidence that evaluation of public science communication activities would become more prominent in future.

[91] MOOC is an acronym for 'massive open online course'.

Lee Berger: We are in the early stages of figuring out how to measure and monitor public science communication meaningfully, but it is beginning to happen. In future, evaluation systems in science will definitely take public engagement into account.

5.3.3.4. Evaluation practices: summary

From my interviews, it was clear that most researchers were interested in more effective evaluation and monitoring of their science engagement efforts, but that they lacked the expertise to get started. My findings confirmed that public science engagement remains a low-priority task for many universities, as was suggested by the South African Council on Higher Education (2010), and that research institutions in the country have a long way to go towards meaningful monitoring and evaluation of public science engagement. This situation is not unique to South Africa, since the challenges of developing and implementing meaningful science communication evaluation tools have been demonstrated in many other countries (Neresini & Pellegrini, 2008; Neresini & Bucchi, 2010; Jensen & Laurie, 2016).

5.3.4. The influence of medialisation

High-profile scientists must be a big thing for the university, because every time you stand up, you promote the university. *(Andrew Forbes)*

Highly visible scientists are probably worth billions of rands[92] to their universities in exposure value. What is it worth to be above the fold on the front page of the **New York Times*****? I bet it is a lot!*** *(Lee Berger)*

Medialisation is about the increased media attention for science, but also relates to the increased orientation of scientists and research organisations towards the media. In this section, I explore and present relevant evidence for the presence of this phenomenon in South Africa, based on my interviews with 30 visible scientists in South Africa.

5.3.4.1. Visible scientists' perceptions of medialisation

"Thirty years ago, scientists did not engage with the media as much as they do now. And the media did not engage with the scientists as much as they do now". Remarks like this one by Rubidge, indicated that visible scientists perceived increased interaction between scientists and media organisations over time. While it was outside the scope of this study to explore trends in media attention towards science in South Africa, my findings generally revealed that visible scientists were aware of the escalating expectations that scientists should become visible via a range of media platforms. As stated by Cathi Albertyn, "It is fast becoming a different world, right? A world that revolves around media."

"I got into serious trouble at one stage because we were not publicly visible enough," Sheryl Hendriks told me. "We were given resources and told to up our game in terms of being publicly

[92] The 'Rand' is the currency in South Africa (ZAR).

visible. That instruction came directly from the top." Remarks like these illustrated that some scientists were under pressure in university environments to become more visible in the public sphere. They typically realised that their institutions valued their public visibility as a way to help build the profile of the university or research council, but they did not necessarily perceive these expectations from their universities as problematic.

> **Bob Scholes**: Scientists who are publicly visible, and have the academic credentials to back it up, are a hugely valuable asset. And, these days, most people recognise that. I don't experience it as a burden if the university calls on me to fulfil a public role.

> **Marcus Byrne**: Wits has been through a tough time the last two years with 'fees-must-fall' protests, and we've just had a senior staff member involved in a sex scandal. So, it really does the university a lot of good to say: 'These are the peripheral things; let's look a bit deeper at our fantastic scientists who are passionate and the work they are doing. These are the men and women teaching here'. Surely, that has to be good for the image of the university and they have a right to do that?

> **Kelly Chibale**: I don't get the sense that the university is putting pressure on people to speak to the media. But, they do a good job of marketing the institution.

> **Hamsa Venkatakrishnan**: We are certainly encouraged by Wits to communicate in public. I think the university sees the profiling of public intellectuals as a part of their marketing strategy. So, there definitely is a commercial incentive behind it. But, we have to remember that our higher-education institutions are facing difficult times. In terms of public communication, we simply have to chart a path that is mutually beneficial. And, I have never been forced to do a media interview that I did not want to do.

For Gouws, however, the pressure to become more visible in the public sphere is directly linked to the institutional demands for generating additional research income. Her opposition to this was "on the record," she said.

> **Amanda Gouws**: We are under pressure to perform public relations for the university, because that helps to bring in 'third-stream money'. I am very much against it. That is not why I became an academic. You become a cash cow for the university. For me, it is not such a big issue, because I've always been in the media, but it is quite bad for some of my colleagues.

There were more reasons why visible scientists were concerned about medialisation pressures, and these concerns were related to the fear that, driven by the pressure to attract media attention, scientists and science organisations could be tempted to inflate the importance of their findings.

> **Bruce Rubidge**: Of course, scientists could manipulate their stories to make it exciting for the media, but I don't think that is the way of integrity.

> **Tim Noakes**: Industry uses research as a marketing tool and that is really dangerous. The same thing can happen at universities. You have to decide what your goal is. Are you trying to educate the public, or are you trying to promote the university? I think universities, by and large, are not very good at educating the public. They don't seem to put that as a high priority. So, then it does become about promoting the university. There is the reverse of that. That

the universities promote the scientists' research way beyond what it is. That's the bigger failing. That's a much bigger danger. And that is why the public is so confused, because every day there is a report out from some or other university making claims about things that scientists have proved, when they have not proved anything of the sort. And, if I see the distortion in my own field, I can imagine what's happening in the totality of science.

Linda Richter: We are often in trouble for the way we report our findings, but we are very worried about misrepresenting our work. When we apply for funding, we draw on the broad body of work and you can make a case for why the work is important. But, when you report your findings, it is only a tiny piece in a much bigger mosaic. And to claim that you have changed the mosaic would make me worry that we are going too far. So, there is this conflict about how to contextualise your work which is really quite a humble part of a much longer-term global effort. So, how can you say 'mine is the big story', when it is not the big story at all? It is a very small part of the big story.

Scholes was not concerned about the potential threat of medialisation for the integrity of science.

Bob Scholes: The risk that science can be distorted by looking for media attention is a lesser problem than the risk of not communicating. Your peers will keep you honest in your science. They will pull you up pretty fast.

5.3.4.2. Awareness of the growing role of science PR

The visible scientists that I interviewed were certainly aware of the role of professional communicators in their institutions. The researchers knew that these professional communicators had specialised skills and networks in the media world.

Bruce Rubidge: The people in our communication office come out of the press environment. They have been employed by newspapers in the past. They understand how newspapers operate.

Mary Scholes: Our communication people keep a list of good journalists in the field of environmental science and we meet with them regularly. Also, before big events like COP21, our marketing department tell them who the experts are inside the institution that could comment on issues.

Some scientists experienced the expectations coming from institutional PR staff as demanding and stressful, while others were more amenable to complying with such requests, especially if they perceived that the media office had assisted them in the past. This was illustrated in contrasting comments by Byrne and Gray (below). Van der Auweraert (2008) also found that some scientists at the University of Antwerp resented excessive demands from university communication staff, indicating that it was not their job to do institutional PR.

Glenda Gray: It is the job of the communication officers to profile the organisation. They use scientists and science stories to do that. So, they want a certain number of articles in the *The Star*[93] and I become their fodder for *The Star*. So, often you don't drive your own agenda. But, the typical reaction they get from scientists is: 'Oh, I don't want to speak to anyone,

[93] *The Star* is a daily newspaper in the Johannesburg area.

> please keep the media away from me!' So, there is a tension. The communicators have to find the balance between the story that needs to be told and the reluctance of the scientists to tell it. A good communication officer will be gentle on the scientist. Sometimes, less is more in the media.
>
> **Marcus Byrne**: The people in the press office have done fantastic things for me when we have had something to promote, so if they ask me to help them, it is kind of a reciprocal obligation. I would have to do it.

There are also scientists who did not perceive any pressure in their institutional environments to become more publicly visible.

> **Jill Farrant**: We are not told to go out and make UCT proud. It is not mandatory at all.
>
> **Anusuya Chinsamy-Turan**: Public engagement is driven by the scientists themselves who want to share their work. There is no pressure from the institution to do it.

5.3.4.3. Medialisation effects: summary

Visible scientists were generally aware of the desire of their institutions to showcase research achievements as a way to boost the image of the organisation, and some noted an increasing expectation from research managers and funders to make their work visible via the mass media. Despite this, the prevalent view was that institutional pressures did not determine their communication efforts. Therefore it is unlikely that medialisation poses a threat to the actual practice of science in South Africa, as has been suggested for other countries (Weingart, 2012; Marcinkowski & Kohring, 2014).

Chapter 6: Reflections on key findings, implications and conclusions

6.1. Introduction

In order for the Department of Science and Technology (DST) of South Africa to implement its proposed science engagement framework successfully (DST, 2014), and for research institutions in the country (and their academic staff) to contribute meaningfully to this government policy directive, it is imperative to identify and clarify the factors that influence scientists' involvement in public science communication. A review of literature relevant to the communication behaviour of scientists confirmed that research of this nature relevant to developing countries, and particularly South Africa, is rare. Therefore, this study aimed to contribute to scientific knowledge by exploring and analysing the factors that influence the public communication behaviour of scientists in South Africa.

The choice was made to focus on publicly visible scientists, who were identified with the help of a science-media panel, since these scientists have experience of the potential motivators, constraints and consequences pertinent to public science communication. Through qualitative, in-depth interviews with 30 visible scientists living and working in South Africa, I identified the motivations and constraints, both extrinsic and intrinsic, which determine whether and how these scientists engage with audiences outside the science community.

The theoretical perspectives on human behaviour and motivation, as presented in Chapter 2, proved to be an appropriate approach to analyse relevant science communication literature, as well as to construct a conceptual framework (Figure 2.4) that underpinned the study. This conceptual framework provided a valid lens that I could use to clarify and categorise findings from earlier studies, as well as to structure the qualitative interviews and interpret the resulting data. In accordance with the theoretical assumptions, my findings confirmed the influence of all three clusters of factors (background, attitudinal and contextual factors), and their constructs, on the public communication behaviour of visible scientists in South Africa. This study provided new insights into the factors that govern the public communication behaviour of visible scientists in South Africa, and revealed how these factors were rooted in the history and present-day challenges of the country. As such, the study contributes to the hitherto inadequate body of knowledge regarding the factors that shape scientists' involvement in public science engagement in the South African context.

Broadly, the following key findings emerged:

- First, the bulk of scientists who are visible in the South African public arena are also productive researchers in the academic arena and leaders in the local science community.
- Secondly, a finding unique to this study highlighted 'population group' as a factor that influenced scientists' motivations to communicate in public and their ability to connect with the culturally diverse audiences in South Africa.

- Thirdly, in terms of the national context, there were specific influences in South Africa, rooted in the history, society and physical environment of the country that compelled local scientists to engage with society.
- Finally, the rest of the interview data largely confirmed findings from earlier research regarding the effect of background, attitudinal and contextual factors. These findings were explicated for the local context, and subtle differences (compared to earlier findings) were revealed.

6.2. Reflections on findings

A comparison of the findings of this study with similar studies in other countries showed that, in many ways, the communication behaviour of South African scientists were motivated and constrained by similar influences compared to those that have been identified before. It is noteworthy that South African scientists responded largely similarly to communication influences compared to scientists in other parts of the world, given the differences in science systems in a developing country versus developed countries. There were, however, subtle differences for many of the factors, and significant differences when it came to population group and the national context. In the section below, I discuss these findings within the three clusters of factors that were examined, namely background, attitudinal and contextual factors.

6.2.1. Background factors

6.2.1.1. Research field

Comparisons of the public communication behaviour of scientists across fields of research have consistently shown differences across and within broad fields of research (as was discussed in 3.2.1). These differences are largely attributed to variations in social distance and selective media interest (Goodell, 1975; Mathews *et al*., 2005; Jensen *et al*., 2008; Peters *et al*., 2012), as well as to variations in the norms that govern the behaviour of scientists across research fields (Peters *et al*., 2012; Peters, 2013; Johnson *et al*., 2014; Wien, 2014). However, the literature also shows that scientists working in remote and esoteric fields of research can and do become influential public communicators (West, 2009; Gazan, 2013; Fahy, 2015).

Perspectives from this study concur with the view that some fields are inherently more appealing to the mass media and/or public audiences for a variety of reasons, such as a perceived relevance to everyday life or the ability to stimulate curiosity or fascinate people. Consequently, visible scientists agreed that some science topics were perceived as much harder to communicate than others, but similarly pointed out that some of the most successful public science communicators in the country worked on abstract topics that were not immediately relevant to everyday life.

These observations suggested that the way a specific topic is communicated might be more important than the topic itself, and that it is possible to make knowledge across all fields of research accessible to external audiences. It follows then that working in a remote or abstract field of research does not preclude active participation in public science communication and that scientists, irrespective of their fields of research, could contribute to public science engagement.

6.2.1.2. Research productivity

Several studies over the last decade have revealed a positive correlation between academic productivity and public visibility (Jensen *et al*., 2008; Bentley & Kyvik, 2011; Jensen, 2011; Wigren-Kristoferson, Gabrielsson & Kitagawa, 2011) (as was discussed in 3.2.2). Equally, this study found that publicly visible scientists were typically highly productive researchers and leaders in the science community, and that their academic productivity contributed to their public visibility by stimulating media and public interest in their work.

The finding that scientists with a high public profile are typically also productive leaders in the science arena was significant. It challenges the perception that scientists who are actively involved in public communication and are visible in public are not serious scientists (The Royal Society, 2006; Burchell *et al*., 2009) or that public communication is a stigmatised and low-status activity that detracts from a scientist's prestige and that is typically undertaken by failed scientists or ex-scientists (Whitley, 1985; Shugart, 2015). For example, Porter *et al*. (2012) found that some scientists still think that being a 'good scientist' and being a 'good communicator' are mutually exclusive.

Instead of doubting the academic standing of science popularisers, the current study agreed with scholars like Goodell (1977), Fahy and Lewenstein (2014), Bucchi (2015) and Fahy (2015) who point out that highly visible scientists represent the scientific elite. This view is further amplified by Shermer's (2002) analysis of the scientific productivity of two well-known science popularisers, Stephen Jay Gould and Carl Sagan, leading him to conclude that being a top scientist and a media-savvy populariser are not mutually exclusive and that the "the 'Sagan Effect' is a Chimera" (Shermer, 2002:493).

The finding that leading scientists are often also actively involved in public engagement raises the issue of the time it takes to participate in public science engagement. The literature shows that 'time constraints' is one of the barriers most frequently mentioned by scientists as a reason why they refrain from or limit their involvement (Andrews *et al*., 2005; Mathews *et al*., 2005; The Royal Society, 2006; European Commission, 2007; Poliakoff & Webb, 2007; Van der Auweraert, 2008; Kreimer *et al*., 2011; Searle, 2011; Allgaier *et al*., 2013b; Smith *et al*., 2013; France *et al*., 2015; McCallie *et al*., 2016; Namihira-Geurrero, 2016). The perception that 'lack of time' is a barrier towards public engagement is, however, challenged by the finding that scientists who are most visible in public are simultaneously productive leaders within scientific circles. Their active involvement invalidates (at least to an extent) the claim that public science engagement is too time-intensive to be accommodated as part of a scholarly career. This finding suggests that scientists who are motivated and willing to participate actively in public communication about their work, will make time for these activities.

As suggested by scholars like Goodell (1977) and Rödder (2012), visible scientists in the current study also perceived a protective effect from their academic reputations, based on their scholarly productivity. They saw public communication as valuable and meaningful, but insisted that academic reputations and scholarly outputs were even more important and provided the basis for being respected as a public expert. Consequently, they emphasised that public engagement should never be pursued at the expense of scholarly work.

In conclusion, the leadership status of publicly visible scientists, as illustrated in the literature and this study, invalidates the notion that scientists who spend time on public engagement necessarily neglect their academic duties or are not serious scientists. This evidence about the active involvement of scientific leaders in public engagement could help to destigmatise public science communication and contribute towards normalising public engagement within a career in science.

6.2.1.3. The influence of age

Studies of scientists' involvement in public communication according to their age generally show that older scientists are more involved compared to their younger colleagues (The Royal Society, 2006; Dunwoody *et al*., 2009; Kreimer *et al*., 2011; Bauer & Jensen, 2011; Dudo, 2013; TNS-BMRB, 2015; Chikoore *et al*., 2016) (as was discussed in 3.2.3). Senior scientists' confidence in their communication abilities stem from their experience over many years, as well as their belief that people are interested in their work (Vetenskap & Allmänhet, 2003; Blok *et al*., 2008; Jensen *et al*., 2008; Searle, 2011; TNS-BMRB, 2015).

In line with these findings, visible scientists in this study perceived that they became better at public communication over time. However, they felt strongly about the need (and even the obligation) to involve early-career scientists in public engagement and generally insisted that it would be counterproductive for young scientists to wait until they reached a certain age or level of seniority before they stepped out to engage with society. The participating scientists emphasised that younger scientists had as much right to academic autonomy as their older colleagues, including the right to communicate their work in the public arena. Furthermore, participating scientists perceived their younger colleagues as ideally suited to engage with young audiences, and were of the opinion that these young scientists were innovative in their approaches to engaging with external audiences, and able to use novel communication tools and platforms. Consequently, they made a particular effort to create engagement opportunities for their younger colleagues.

This strong support for including young scientists in public science communication and the willingness of visible scientists to put their students forward when media crews visited their laboratories conflict with the general pattern in science that public communication should be done by senior leaders in the field (Goodell, 1977; Greenwood & Riordian, 2001). It is also in contrast with the finding by Burchell *et al*. (2009) that even senior academics who regard public communication as important often do not encourage younger colleagues to get involved.

By contrast to the findings amongst the visible scientists in this study that young scientists could and should communicate in public, earlier studies show that young scientists are considerably less involved in public communication compared to their senior colleagues (MORI, 2001; The Royal Society, 2006; Kreimer *et al*., 2011; Bauer & Jensen, 2011; TNS-BMRB, 2015; Chikoore *et al*., 2016). The literature shows that the relative inexperience of junior scientists makes them apprehensive and uncertain when it comes to public engagement (Bond & Paterson, 2005; Mizumachi *et al*., 2011; TNS-BMRB, 2015) and that they may avoid public communication activities due to perceived academic pressures and fears of negative consequences (Gwynne, 1997; Jensen *et al*., 2008; Van der Auweraert, 2008; Rödder, 2012; Horst, 2013).

Visible scientists in this study agreed that public communication could be a high-risk undertaking for young scientists, but nevertheless insisted that they had an important role to play in engaging public audiences. It may be particularly meaningful for young researchers if their supervisors or line managers put them forward for media interviews, since it would take away the fear that their immediate supervisors would disapprove of their involvement in public engagement – a concern amongst young scientists noted by several scholars (e.g. Van der Auweraert, 2008; Rödder, 2012).

Studies show that older and younger scientists typically participate in different ways when they communicate with the public, with older scientists prioritising media and policy interactions (Peters *et al*., 2008b; Dunwoody *et al*., 2009; Petersen *et al*., 2009; Bucchi & Saracino, 2012) and younger scientists favouring youth interactions and social media (European Commission, 2007; Claessens, 2008; BBSRC, 2014; Pew Research Center, 2015a). In line with these findings, scientists participating in this study were aware that their younger colleagues had the edge when it came to engaging with young people and using social media.

The interviewees thought that scientists across all age brackets and seniority levels have a role to play in public science engagement. Despite the acknowledgement that young scientists may face some risks, the findings accentuate the perceived need for young scientists to participate. Therefore, while acknowledging that confidence and skills improve as scientists mature, age is not considered to be a deciding factor in determining whether or not scientists participate in public communication.

6.2.1.4. The influence of gender

Amidst contradictory findings about whether male or female scientists are the most active public communicators, earlier studies generally highlight gender-based disparities in scientists' public communication involvement (Andrews *et al*., 2005; The Royal Society, 2006; Crettaz von Roten, 2011; Jensen, 2011; Kreimer *et al*., 2011; Ecklund *et al*., 2012; TNS-BMRB, 2015), exemplified by negative stereotypes and normative influences that inhibit or downgrade the involvement of female researchers (The Royal Society, 2006; Ecklund *et al*., 2012; Johnson *et al*., 2014). Research on the influence of gender on public science communication was presented in 3.2.4.

Correspondingly, visible scientists had mixed views about the pertinence of gender as a factor that would influence a scientist's willingness and ability to participate in public science engagement. Most respondents agreed that female scientists faced particular challenges in terms of achieving public visibility, and they frequently linked these challenges to the predominantly patriarchal nature of many cultural groups in South Africa, as well as the persistent prevalence of gender stereotypes in society. For example, in line with findings that women are frequently judged on their appearance (Chimba & Kitzinger, 2010), and that a feminine appearance has a negative influence on women's science careers (Banchefsky *et al*., 2016), some of the publicly visible female scientists I interviewed felt the need to downplay their femininity in order to be taken seriously in male-dominated research environments.

Female scientists in the current study were furthermore cognisant of how differential, gender-based role expectations made it harder for young women, compared to their male counterparts, to balance personal, family and career demands. Consequently, the perceived need and duty to combat these stereotypes emerged as a key motivator towards public engagement for several of the female scientists.

Notably, several respondents pointed out that, in their view, the issue of gender-based biases in science were becoming less prominent over time. Overall, respondents mostly agreed that a scientists' gender could influence her/his communication behaviour, but that both men and women had important roles to play as visible scientists in the public arena.

6.2.1.5. The influence of population group

For my literature review, I collected 107 articles based on earlier research that have investigated scientists' communication behaviour. None of these studies explored whether population group (or race/ethnicity) affected scientists' participation in public engagement. This issue was discussed further in 3.2.5.

While the literature does not specifically present evidence about population group as a factor that influences scientists' communication behaviour, it does show that scientists are motivated by the objective of inspiring young people in order to recruit future scientists (The Royal Society, 2006; Holliman & Jensen, 2009; Illingworth & Roop, 2015), and that some particularly try to attract under-represented groups (Martín-Sempere *et al*., 2008). Scholars generally agree that black role models have a pertinent influence on attracting young black people to careers in science (Hall & Post-Krammer, 1987; Fahy, 2015), and that black scientists are particularly credible role models in terms of connecting with black audiences (Joubert, 2007; Blair, 2012; Idowu-Onibokun, 2017). Furthermore, personal contact with scientists are believed to have an effect on science-related career choices (Hill, Pettus & Hedin, 1990; Buck, Plano Clark, Leslie-Pelecky, Lu & Cerda-Lizarraga, 2008; Lee, 2011). The perceived influence of population group on journalists' expectations during interviews with scientists, as described by DeGrasse Tyson (2004), provides further cause to reflect on the relevance of population group when exploring scientists' communication behaviour.

Furthermore, several interviewees have commented on the relevance of cultural diversity to science engagement practice and have discussed the challenges of communicating science in multicultural and socially diverse societies, as has also been noted by scholars (e.g. Ogunniyi, 1996; Joubert, 2001; Lewenstein *et al*., 2002; Manzini, 2003; Fayard, Catapano & Lewenstein, 2004; Medin & Bang, 2014; Fish *et al*., 2017; Lelliot, 2017). In addition, cultural diversity and social inclusion in science communication have been prominent themes in regional and international science communication conferences (Ogunniyi, 1996; Keogh, 1996; Joubert, 2003, De Semir *et al*., 2004; Fayard *et al*., 2004; Treffry-Goatley, 2014).

My findings showed that black scientists were underrepresented in the group of 211 visible scientists that were identified by a science-media panel, with only 47 (22%) black researchers, while black researchers in South Africa constitute 42% of the scientific workforce, and black people constitute 92% of the total population. (A more detailed breakdown of these figures was provided in 4.2.) Accordingly, interviewees noted that black scientists were still largely invisible in South African society.

More than two thirds of the visible scientists I interviewed perceived notable differences in the motivations and barriers towards public engagement between black and white scientists, including apparent biases and prejudices that were perceived to make it more challenging for black scientists to establish themselves as experts in the public sphere. In response, black scientists perceived a particular responsibility to dispel negative attitudes by becoming visible in public and demonstrating their expertise and leadership in science. Importantly, interviewees noted that they perceived this situation regarding negative biases towards black scientists to be improving and that black scientists were increasingly in demand as public experts.

Overall, the visible scientists I interviewed were highly cognisant of the importance of achieving cultural resonance when communicating science, and this awareness was informed by the multi-cultural nature of South African society. Mindful of the need to diversify the scientific workforce in South Africa, participating scientists prioritised communication with young, black audiences, hoping to inspire them about careers in science.

Visible scientists interviewed for this study, particularly white males, thought that they were not ideally suited to engage with black youths. Instead, young black scientists who were able to speak one or more of the indigenous African languages in South Africa, were regarded as ideal role models. Therefore, these scientists felt strongly about the need for young black scientists (in particular, women) as role models to attract young people to careers in science. This emerged as the most important reason why South African scientists accentuated the need to involve younger colleagues (especially black and female scientists) in public engagement activities, as well as to provide science communication training for graduate science students.

A key finding from this study is therefore that population group is linked to cultural (and language) resonance, which is perceived (by the scientists who participated) to influence a scientist's ability to connect with a specific audience. Based on these perceptions, scientists who have to engage with multiple audiences prefer to allocate the communication opportunities to a staff member who fits the cultural profile of the intended target audience. Consequently, the population group to which a scientist belonged was perceived to be a key determinant of effective engagement with a particular audience.

6.2.2. Attitudinal factors

6.2.2.1. The effect of scientific norms

My literature review explicates the influence of scientific norms on the way scientists communicate, both inside and outside the scientific arena (as summarised in 3.3.1). Traditionally, scientific norms were perceived to penalise or at least restrict outward-facing communication (Goodell, 1975; Gunter *et al*., 1999; Brown *et al*., 2004), but more recently scholars have noted that these norms are changing towards greater approval of scientists who become publicly visible (Peters *et al*. 2008a; Searle, 2011; Rödder, 2012; Peters, 2013; Marcinkowski *et al*., 2014).

Despite the growing acceptance of scientists' visibility in public life, some normative concerns remain, for example concerns that scientists may become increasingly focused on the potential of media coverage and public prominence to compete for attention, which is expected to lead to political support and funding (Koh *et al.*, 2016; Weingart & Guenther, 2016). This could lead to the 'medialisation' of science (Weingart, 1998, 2012), i.e. an orientation to attention by the media that could even affect the research agenda of science (Peters *et al*., 2008; Rödder, 2011, Peters, 2012; Weingart, 2012).

The potentially detrimental effects of medialisation could manifest in a number of ways. One example refers to when scientists, in a bid for public and political support, release their findings to the media prior to peer review. This famously happened in the 'cold fusion' case (Lewenstein, 1992b), as well as in the case of the 'human genome project' (Rödder, 2009). In South Africa, researchers from the University of Pretoria caused an uproar when they bypassed ethical standards while testing a supposed cure for HIV/Aids and announced their findings regarding Virodene[94] to the press (Sidley, 1997). Another potential outcome of medialisation is purported to be hype, exaggeration and sensationalising in the communication materials produced by scientists and/or the professional communicators at research institutions (Weingart, 2017a; Marcinkowski & Kohring, 2014), a practice which is deemed to be deceptive and contradictory to the ethical principles of scientific communication, ultimately undermining public trust in science (Weingart, 2002; 2017a).

Persistent normative concerns, at least at a collective level in the science community, mean that participation in public science communication remains a contested activity as viewed from within the science arena (Casini & Nerisini, 2012; Rödder, 2012), but these constraints contrast with increasing calls on scientists to make their research more accessible to society and to engage more

[94] Virodene was later found to be a highly toxic industrial solvent (Amon, 2008).

pro-actively with public audiences. Paradoxically, therefore, public science communication is perceived as both an altruistic and a self-serving activity.

On the one hand, leaders in the scientific world frame public science communication as a virtuous activity driven by noble motives, i.e. something that scientists do for the good of society and for little personal reward (Bodmer, 1985; House of Lords, 2000; Leshner, 2003). Seen from this perspective, public science communication is regarded as a moral obligation and scientists who avoid it may be criticised for hiding in the proverbial ivory tower and ignoring calls from society for greater transparency and social responsiveness, thereby risking public and political support for science in the long term.

On the other side of this debate, public science communication is deemed to be a tainted enterprise, characterised by battles for attention, driven by special interests and exploited for hidden agendas, and used primarily to compete for reputation and money (Weingart, 2002; 2017a). Weingart and Guenther (2016) highlight how political motives, such as the drive to democratise science and justify public spending on science have transformed public science communication from a "well-meaning activity" (2016:1) into "politically motivated propagandistic communication of science" (2016:3) where PR experts take over from scholars and science communication becomes a branding and marketing exercise. They also point out how new demands of public management cause scientist to go along with the logic of trying to reach as many people as possible. Seen from this perspective, institutions and individual researchers invest time and money in order to promote themselves, rather than to serve the public good. This increased media orientation of science may have unintended consequences, including backlashes on science and scientists themselves (Weingart, 2002; Schäfer, 2011; Marcinkowski & Kohring, 2014).

Views about the effects of a high public profile on scientists' career prospects are equally inconsistent, with some scholars and studies suggesting that publicity and public engagement could detract from scientific status and credibility (Burchell *et al*., 2009; Johnson *et al*., 2010; Weingart, 2002, 2012; Porter *et al*., 2012), while others position a high media profile as a pathway towards enhanced academic leadership and policy influence (Von Grebmer, 2000; Marincola, 2003; Shanley & López, 2009; Vucetich & Nelson, 2010; Baron, 2010b; Fuller, Grant & Baum, 2015). A study by Porter *et al*. (2012) found that getting involved in public campaigning for a specific position in science might cause participating scientists to face a series of difficult choices, irreconcilable tensions and counterproductive consequences.

The same tensions apply to public science communication by research institutions. Growing expectations that these organisations should make their work visible and accessible to society (Gibbons, 1999; South African Council on Higher Education, 2010; Haywood & Besley, 2014; Shipman, 2014), along with the politicisation of science and fundamental changes in the public management of science (Scheufele, 2014; Hoffman, 2016; Weingart & Guenther, 2016) have resulted in a significant growth of public relations within science (Marcinkowski *et al*., 2014; Shipman, 2014; Woolston, 2014). However, the question now emerges whether institutions are sincerely responding to a societal demand when they invest in institutional science communication, or whether they are primarily communicating in order to promote themselves and compete for resources (Kohring *et al*., 2013; Marcinkowski & Kohring, 2014).

Not surprisingly, these contradictory views on science communication result in ambivalence amongst scientists about the desirability of becoming publicly visible (Rödder, 2011) and a perceived need on the part of scientists to perform a balancing act between doing “too much or too little media work” (Porter *et al*., 2012:415). Davies (2013) points out how public engagement is increasingly advocated and demanded, but simultaneously constrained by lack of support and fears regarding influence over careers. Under these conditions, Bauer and Jensen (2011:8) find that public science engagement remains “a marginal call’.

Similarly, Burchell *et al*. (2009) describe public engagement as a professional anomaly: it is increasingly acknowledged and valued, but simultaneously seen to be under-incentivised and under-rewarded, potentially detrimental to research, and professionally stigmatising. Interview data from the study by Burchell *et al*. reveal how scientists reject the idea that they do public engagement for self-promotion, but that they nonetheless fear being seen in this way by their peers, or worse, being regarded as inadequate scientists.

Burchell (2015) points out that scientists’ perception of the importance of science communication (with many acknowledging it as a duty) becomes less certain when their other professional duties and time pressures are brought into the picture. Along the same lines, Watermeyer (2011) concludes that many scientists feel indecisive and anxious about public engagement, based on uncertainty about the legitimacy of public engagement as a core academic activity and the role of academics in communicating with public groups.

Scientists’ ambivalence about public engagement was equally apparent in the current study. For example, Bruce Rubidge acknowledged the merit of university leaders recognising scientists who achieve publicity for the institution, but equally pointed out the resentment that is likely to result from colleagues if a particular scientist becomes ‘the headmaster's pet’. Several interviewees remarked that Lee Berger was criticised within the science community for his high public profile, often adding that they thought he was criticised unfairly. While participating scientists did not perceive a major impact of normative restrictions on their own communication efforts, they were acutely aware of the potential influence of normative sanctions as a communication deterrent, especially for early-career researchers.

Views from my interviewees echoed the earlier opinion that norms in science are changing towards greater acceptance of public communication of science, largely as a result of a growing awareness of the importance of fostering public and political support for science (Burchell *et al*., 2009). Several interviewees mentioned that they perceived a growing expectation from research funders to plan for and report on public science engagement as part of the research funding application and/or reporting process.

Reflecting on the contradictions and tensions regarding public science communication, it could be argued that the ethicality (both personal and institutional) of science communication activities is judged according to its objectives. The key question is, why are scientists (and scientific institutions) communicating? Are they doing it to promote and benefit themselves, or are they doing it for the public good? Porter *et al*. (2012) frame these tensions inherent to contemporary science communication as a balancing act between 'promoting science' versus 'promoting scientists', and the tensions between 'engaging the public' versus 'publicising research'. The authors admit, however, that these lines are blurred at times and that it may not be helpful to make these distinctions since the fates of science and scientists are entwined. Similarly, Weingart and Guenther (2016) concede that even large-scale and PR-driven science communication campaigns might have an educational component.

While institutional science communication outputs (press releases, research reports, web sites, etc.) are likely to be motivated primarily by promotional aims, scientists themselves may be motivated by a much more complex mixture of objectives (People Science & Policy, 2002; Rowe & Frewer, 2005; Borchelt & Hudson, 2008; Marcinkowski & Kohring, 2014; National Academies of Science, Engineering and Medicine, 2017; NCCPE, 2016; Sánchez-Mora, 2016). Similarly, a range of promotional, educational and dialogic goals are presented in the proposed science engagement framework for South Africa (DST, 2014) and my interview data confirmed that the visible scientists who participated were motivated by a multifaceted and diverse blend of communication objectives.

It may therefore be more constructive to acknowledge that "individual researchers tend to have a range of motivations and objectives in mind when they conduct public engagement, usually simultaneously" (Burchell, 2015:26), as well as they they represent many different interests (or "collectives") when they communicate in public, as suggested by Davies and Horst (2016:54). It follows that there are typically a range of strategic agenda behind scientists' participation in public communication, and that a specific communication event may present "a mix of academic content, social obligations, and branding opportunities" which may include a genuine effort to engage people in science (Davies & Horst, 2016:57). Consequently, Davies and Horst argue, it does not make sense to try to differentiate between communication activities that are aiming for public good and those that aim for reputation building.

Scientists' communication objectives became apparent via the nature of the public communication activities they participated in, as related to me during the interviews for the current study. Some of these were highly visible activities such as addressing international press conferences, being interviewed on television or doing a TED talk. Other activities had a local focus, such as presenting a talk at a school or talking to patients waiting at a municipal clinic. Clearly, different agendas and objectives are embodied in such divergent activities, but it is equally reasonable to suggest that, across these examples, the participating scientists were representing their institutions and were aiming to convey information about science, and even to encourage public dialogue.

In addition to mentioning a range of educational, trust-building, policy and defensive objectives that motivated them to engage with society, a number of the scientists I interviewed readily admitted that they also communicated with external audiences in order to raise funding, and that this was achieved via promoting their own profiles and the reputation of their research group or institution. In several earlier studies, scientists equally acknowledged that they communicated with public audiences in order to raise funding for their research (e.g. Reed, 2001; Peters *et al*., 2008a; Sturzenegger-Varvayanis *et al*., 2008; Searle, 2011; Escutia, 2012; Allgaier *et al*., 2013a; Marcinkowski *et al*., 2014). Communicating in order to gain research money is generally viewed negatively and may even be distrusted (Fiske & Dupree, 2014; Nisbet & Markowitz, 2015a; Koh *et al*., 2016). However, in increasingly competitive research environments, the objective of raising money for research may become normatively more acceptable. In the United States, for example, the perceived need to demonstrate the dividends of research investments has resulted in training programmes where scientists are taught the skills of presenting their research and its outcomes in plain language to investors, journalists and policymakers, such as Research!America (Brown *et al*., 2004) and the Aldo Leopold Leadership Programme (Gold, 2001).

Interestingly, two of the very visible HIV/Aids researchers that I interviewed, Glenda Gray and Linda-Gail Bekker, challenged the perception that communicating with the objective of raising money was unethical or at least questionable. Both were of the opinion that raising money for research was an integral part of their responsibilities, and that they would be failing South Africans if they did not do everything in their power to raise as much money as possible for health (and specifically HIV/Aids) research. Moreover, they acknowledged that having a high public profile, both personal and institutional, and arranging events to attract media attention, were an integral part of raising money. As an example, Linda-Gail Bekker said that the main reason for the biennial International Aids Conference was to sustain political support and funding, and mentioned how they invited royalty and celebrities in order to attract maximum media attention. (Prince Harry, Elton John, Bill Gates, Princess Mabel of Orange-Nassau and Charlize Theron counted amongst the celebrity guests at the 2016 conference.) Porter *et al*. (2012) agree with the view that interested public communication is not necessarily morally unsound, agreeing with Gray and Bekker that a high public profile can deliver much-needed resources necessary to update research equipment and sustain quality research.

In conclusion, my literature review and interview data showed that normative influences on science are multifarious and fluid, and that scientists are faced with opposing expectations and demands concerning their visibility. These normative influences in South Africa are largely similar compared to what emerged from earlier studies, with an overall indication of a growing demand for public science engagement, but persistent concerns over potentially negative outcomes, unintended consequences and harmful medialisation effects.

6.2.2.2. Scientists' attitudes towards the public

Surveys since 2000 have revealed that scientists around the world generally have a negative view of the public, seeing them as largely ignorant and irrational when it comes to science (MORI, 2001; Vetenskap & Allmänhet, 2003; Mathews *et al*., 2005; Agnella *et al*., 2012; Besley & Nisbet, 2013; Braun *et al*., 2015; Dudo & Besley, 2016). Research on this topic (i.e. how scientists feel about the public) was discussed in 3.3.2. By contrast, visible scientists in South Africa were mostly positive about the public and thought that the public were interested to hear from them about new advances in research.

Given the diversity of the publics for science in a country like South Africa (Guenther & Weingart, 2016), it was noteworthy that the scientists I interviewed displayed an awareness of the need to segment audiences, cater for different levels of interest, varied information needs and communication preferences. Their perceptions of audience diversity were commonly linked to different socio-economic levels, and scientists were attentive regarding the adaptation of their content and delivery according to the needs of the audience. This awareness of audience diversity contrasts with earlier studies which found that public science communication is often seen as an activity aimed at a vague and anonymous mass, i.e. 'the general public', 'the man on the street' or 'the taxpayer', and that scientists routinely fail to prioritise specific target audiences (MORI, 2001; Van der Auweraert, 2008). Still, science communication scholars emphasise the importance for scientists to identify and understand the audiences with whom they wish to engage (Lewenstein, 1992a; Stilgoe & Wilsdon, 2009; Mooney, 2010), as well as to acknowledge and cater for diversity in public audiences (Turney, 2006; Casini & Neresini, 2012; Bucchi & Trench, 2014). In general, researchers are urged to be more specific and strategic when considering participation in public communication activities (Borchelt, 2001; Burns *et al*., 2003; Turney, 2006; Bucchi & Trench, 2014; Irwin & Horst, 2016; Besley, 2017).

In terms of the priority audiences for South African science, visible scientists generally felt that decision-makers and policy-makers (in government and the private sector) were the most important target groups with whom they needed to engage. Many of them were also passionate about sharing their science with young people. Their motivations for engaging with decision-makers were linked to seeking support for science, while educational motives drove their desire to engage with youth groups. In particular, visible scientists wanted to help overcome the educational imbalances of the past and inspire a new generation of young scientists that could constitute the future science base in South Africa.

The idea that the public could be active participants in the process of science (Einsiedel, 2007) and the belief that publics have a right to participate in science policy deliberations have gained ground in recent years (Wilsdon & Willis, 2004; Wilsdon *et al*., 2005; Stilgoe & Wilsdon, 2009; Stilgoe *et al*., 2014). Public opposition to emerging technologies, and particularly the way public debate has affected and politicised biotechnology research, heightened awareness of the need for timely public engagement and informed debate between science and society when it comes to emerging technologies with potential moral and ethical implications (Priest, 2006; Nisbet & Scheufele, 2009; Scheufele, 2013, 2014). Scientists involved in fields such as nanotechnology and synthetic biology are therefore keen to avoid the perceived mistakes made during the public GM debate and the objective of nurturing and sustaining public trust in science has become paramount (Weingart, 2002; Wynne, 2006; Gauchat, 2011; Resnik, 2011; Fiske & Dupree, 2014). While visible scientists in this study were not unwilling to involve the public in debate and decisions about science, and believed that public involvement was morally justified, they doubted whether the appropriate structures for meaningful public participation in science existed in South Africa.

Visible scientists in the current study emphasised their role in providing accurate and factual information about new research to the public, particularly in fields related to public health. They felt that scientists had a particular obligation in this regard, given the high prevalence of tuberculosis and HIV/Aids in South Africa, and they believed that effective public communication could help combat the spread of such diseases. They accentuated the responsibility of scientists to speak up against misinformation in the public sphere, particularly when pseudoscientific claims could cause desperate and vulnerable people to put their trust in fake cures. These views of scientists in the current study echoed scholarly opinion that the public has a right to know about new advances in science since access to scientific knowledge could help people to make better decisions that could affect their quality of life (Durant *et al*., 1989; Braun *et al*., 2015), as well as that scientists have a moral obligation to "advocate [on behalf of the latest scientific evidence] to the best of their ability in the interest of helping society" (Vucetich & Nelson, 2010:49). A notable finding from this study was that most visible scientists in South Africa would not hesitate to take on an advocacy role regarding a certain issue in science when they felt it was justified, as long as their position was evidence based.

In response to current world events, interviewees were generally concerned about a perceived increase in populist and anti-science sentiments that could undermine the authority of science and they perceived a collective role for scientists to stand up and speak out on behalf of science. These concerns demonstrated that they were aware of how changes in the global socio-political environment could have an influence on the local science–society relationship, and that they were motivated to defend science in the public sphere.

6.2.2.3. Scientists' attitudes towards public communication

As could be expected of scientists with high public profiles, the visible scientists interviewed for the current study were mostly positive about public communication and perceived it as an important and meaningful part of their roles in society. In the past, science communication studies showed that, for most scientists, public communication remained a low-status and stigmatised undertaking (Whitley, 1985; Shortland & Gregory, 1992), and something that they viewed as a peripheral and optional activity (Checkoway, 2001; The Royal Society, 2006; France *et al*., 2015). Relevant research was summarised in 3.3.3. By contrast, the views of visible scientists in South Africa resonated more closely with recent surveys revealing that scientists increasingly recognise the potential value of public engagement (McCann *et al.*, 2015; TNS-BRMB, 2015). It remains clear, however, that scientists have dissimilar attitudes towards public engagement (Jensen; 2011; Marcinkowski *et al.*, 2014) and that they perceive both benefits and disadvantages when they get involved (Allgaier *et al.*, 2013b). The perception of both risks and rewards resulting from public communication was also apparent amongst the visible scientists whom I interviewed.

6.2.2.4. Scientists' attitudes towards mainstream media

Typical of visible scientists elsewhere (Goodell, 1977; Fahy, 2015) (as was summarised in 3.3.4) participating scientists were mostly positive about working with the mass media and they recognised the pivotal role of the media in making science accessible to large parts of society. Scientists interviewed for the current study generally welcomed media attention and saw it as a validation of their positions as experts and opinion leaders in South African society. An understanding of how the media works, good relationships with individual journalists and a willingness to adapt to media needs, allowed visible scientists in the current study to use the media strategically to achieve their communication objectives. My findings regarding the constructive and largely positive interactions between visible scientists in South Africa and the mass media corresponded with recent surveys that point towards an improvement in science–media interactions (Peters *et al.*, 2008a; Peters *et al.*, 2008b; Dunwoody *et al.*, 2009; Wien, 2014; Pew Research Center, 2015a) and resonated with findings by Peters *et al.* (2008) that research leaders and research-productive scientists have regular contact with the media.

However, despite being well aware of the probable payback of working effectively with journalists, visible scientists were wary of the potential drawbacks and problems that could result, especially when working with journalists who were not specialised in science writing. In this regard, they were keenly aware of the challenges faced by traditional media and the dwindling numbers of science journalists in the country. Their fears concerning media interactions mostly related to perceived inaccuracies and hype in journalistic science coverage, as has been shown by other studies (Bucchi & Saracino, 2012; Corley *et al.*, 2011; Gonon *et al.*, 2012). Consequently, despite their own confidence in dealing with the media, visible scientists perceived media interviews as a potentially high-risk activity, especially for their younger colleagues.

6.2.2.5. Scientists' attitudes towards social media

Participating scientists' perceptions of and responses to social media were in line with earlier findings about scientists and social media that revealed a slow and uneven adoption of social media tools within science, resulting from a general lack of skills and confidence concerning the effective, responsible and safe use of these communication channels (Butler, 2005; Gregory, 2009; Scanlon, 2012; Collins *et al.*, 2016). Research about scientists' responses to social media was summarised in 3.3.5. Just like their peers around the world, local scientists have divergent attitudes towards social media, with some embracing it readily, and others avoiding it, with some hesitant fence-sitters in the middle.

Visible scientists who used social media enthusiastically, saw it as a powerful tool for amplifying their reach and impact, both publicly and academically, a view that is endorsed by some scholars and recent studies (Eysenbach, 2011; Priem *et al*., 2012; Bik and Goldstein, 2013; Brossard, 2013; Darling *et al*., 2013; Liang *et al*., 2014; Yeo *et al*., 2014; Collins *et al*., 2016). Those who avoided it, viewed social media as risky, and not suitable as a science communication platform. They generally highlighted the downsides of social networks (see, for example, Mandavilli, 2011). Scholarly opinion on social media as a science communication tool generally admits the power and potential of these platforms, balanced by an acknowledgement of potential risk and the need for regulation, but also recognises that the realities of fast-expanding digital information environments necessitate a careful re-assessment of the science–society interface (Brossard, 2013; Brossard & Scheufele, 2013; German National Academy of Sciences, 2017).

My interview data confirmed that scientists' attitudes towards social media have a direct effect on their adoption and use of these new media channels. It is noteworthy that the two most visible scientists in the current study (Lee Berger and Tim Noakes) used social media intensively, suggesting that these platforms might have contributed to their public visibility.

6.2.2.6. Scientists' perception of a moral duty to communicate

The majority of visible scientists shared the view that they had a moral duty to share their research with public audiences, and their sense of duty was heightened by the perceived inequalities and societal challenges in South Africa, as has also been suggested by Manzini (2003). Scientists whose research was closely linked to particular communities, perceived a particular obligation to make their work visible and accessible to those people, as a way of acknowledging the important contributions of the research subjects. This perceived duty towards the public emerged as a strong motivator for visible scientists in my study to engage with society. Interestingly, one of the participating scientists (Cathi Albertyn) insisted that scientists had a right to speak to the public, rather than a duty.

Local scientists' perception of a duty towards society concurs with the majority view amongst their international peers (Reddy, 2009; Dickson, 2010; Miller & Fahy, 2010; Corley *et al*., 2011; Felt & Fochler, 2012; Wien, 2013; Dijkstra *et al*., 2015) (as summarised in 3.3.6). For example, Massarani and Peters (2016) found that scientists in Brazil are motivated to participate in public debate so that their expertise can improve conditions in society. Clearly, the perception of a public duty compels scientists to communicate with public audiences, including those who do not agree that it should be an obligatory requirement for all scientists. As such, scientists' perception of this public duty is considered one of the key factors that influence their public communication behaviour.

6.2.2.7. Scientists' perception of self-efficacy

The current study confirmed the importance of scientists' confidence in their own abilities when it came to public communication of science, as has been demonstrated in the literature (Poliakoff &

Webb, 2007; Besley *et al*., 2012; Dudo, 2013; Besley, 2014; Dudo *et al*., 2014) (as summarised in 3.3.7).

While visible scientists were generally self-assured regarding their own communication skills, they perceived a lack of public communication skills within their research teams and expressed a need for more science communication training. In particular, they emphasised the need to provide communication training to young scientists systematically and continuously throughout their early careers, preferably starting during their undergraduate studies. The support of visible scientists for science communication training is significant, since studies have consistently demonstrated how quality training could improve scientists' confidence and increase their interactions with the mass media and other audiences (e.g., Gascoigne & Metcalfe, 1997; Gunter *et al*., 1999; MORI, 2001; Ruth *et al*., 2005; Besley & Tanner, 2011; Crone *et al*., 2011; Ecklund *et al*., 2012; Dijkstra *et al*., 2015; France *et al*., 2015; TNS-BMRB, 2015). A recent report from the German National Academy of Sciences (2017) acknowledges the value of science communication training courses in helping interested scientists to engage with mainstream media, as well as social media channels, but recommends that such training should not be made compulsory.

However, despite their strong views about the need for science communication training, visible scientists in the current study did not allocate time to science communication training in their graduate programmes, and noted the difficulties of doing so. Instead, they tried to give their colleagues and students practical opportunities to do public talks and participate in outreach activities. This means that research students and young scientists were rarely (or never) introduced to the theoretical basis for public science communication and the science communication research that underpins public science engagement practice. In this regard, Leshner (2007) highlights the need for specific training in public science communication, arguing that these specialised skills cannot be assimilated during the course of postgraduate work.

In terms of the type of skills required, most visible scientists mentioned popular-level presentations as a key requirement, while a few also highlighted popular writing skills. The fact that their perceptions of science communication skills were mainly limited to public speaking and popular writing, demonstrated a lack of awareness of the potential need to equip young scientists with more advanced skills that are relevant to contemporary public science communication, such as a critical and reflective understanding of how the mass media operates in society, meaningful engagement with science policymakers, understanding of the socio-psychological underpinnings of communication as a science, and an appreciation of ethics in public engagement.

Based on these findings, it seems as if visible scientists in the current study mostly paid lip service to the importance of science communication training, and have given little thought to the scope and nature of training that would optimally support effective public science engagement in their research groups. Furthermore, they have not considered the nature of communication objectives that would be most appropriate when providing science communication training, as highlighted by

Dudo and Besley (2016), as well as by Besley *et al.* (2017). Also, they gave no indication of awareness of the availability of suitable science communication training opportunities in South Africa.

6.2.2.8. The effect of scientists' personality traits

Goodell (1975) elaborates on the clichéd portrayal of scientists as shy, reserved and introverted individuals, but adds that visible scientists typically do not fit this stereotype. At least some of the visible scientists included in the current study were reminiscent of the outspoken and passionate scientists who have a high profile in society, as described by Goodell (1975), Logan (2003), Nathoo (2009), Fahy (2015) and Kraus (2015).

Scholars have noted the lack of empirical evidence about a link between scientists' personality types and communication behaviour (Van der Auweraert & Van Woerkum, 2007) (as summarised in 3.3.8). However, Tsfati *et al*. (2011) found that being introverted makes scientists less willing to agree to media interviews, while Porter *et al*. (2012) suggest that scientists who are articulate and confident are more likely to become involved in public engagement. Accordingly, my respondents were aware that being outgoing by nature made it easier for some of them to engage in public debates and sustain public visibility. However, several visible scientists in the current study accentuated that they were naturally introverted, and that, for them, communicating effectively in public spaces required dedication, preparation and effort. Therefore, while scientists' personalities were validated as a factor that could influence their attitudes to public communication and the nature of the activities in which they chose to participate, personality type was not seen as a barrier that would necessarily exclude some individuals from participating in public engagement.

6.2.2.9. Scientists' perceptions of extrinsic and intrinsic rewards

Visible scientists in South Africa perceived both concrete and abstract rewards resulting from their involvement in public science communication and were therefore motivated to communicate by a mix of extrinsic and intrinsic rewards. Accordingly, the science communication literature highlights the value of both tangible and intangible rewards when considering the motivations that drive scientists to communicate with external audiences (Tsfati *et al*., 2011; Dudo *et al*., 2014) (as summarised in 3.3.9). While it was clear that visible scientists in the current study cared about extrinsic rewards (money, reputation, attention), this type of reward was not perceived to be a prerequisite for involvement.

In accordance with the views of Rödder (2012) and Johnson *et al*. (2014) that scientists care first and foremost about the scientific reward system, most visible scientists in the current study rated their scholarly reputations and academic productivity as more important than any tangible rewards that may result from public communication. Furthermore, many participants experienced an overlap of personal and career benefits from a high public profile, since public visibility was perceived to enhance visibility in academic circles, associated with the ability to compete for students, collaborators and funding. The perception that public and media visibility has the potential to increase academic recognition is validated in studies by Phillips *et al*. (1991), Kiernan (2003), Eysenbach (2011) and Liang *et al*. (2014).

One of the most interesting findings from the current study was that visible scientists in South Africa valued connections and enjoyed interactions with members of the public. Just like scientists in other countries (Pearson *et al*., 1997; The Royal Society, 2006; Wilkinson *et al*., 2011; Kuehne *et al*., 2014) visible scientists in the current study described the responses they experienced from public audiences as one of the most energising and satisfying aspects of their public engagement activities. They emphasised the motivational value of intrinsic rewards, such as the feelings of self-worth which they obtained from participating in public engagement. They told me how community interaction invigorated them to carry on with their research, and how seeing people's curiosity and getting public feedback inspired them. Moreover, several interviewees noted how the challenge of presenting research to lay audiences helped them to clarify their own research and sharpen their own ideas. Overall, scientists derived intense gratification from engaging with the public and even admitted that these activities boosted their own egos.

In line with my findings, the importance of intangible, rather than concrete, rewards surface regularly in science communication literature (Poliakoff & Webb, 2007; Dunwoody *et al*., 2009; Miller & Fahy, 2010; Kreimer *et al*., 2011; Dudo, 2013) and a wide range of intrinsic rewards that result from scientists' participation in public communication (related to enjoyment, personal development, satisfaction, meaning and self-esteem) have been demonstrated in earlier surveys (Pearson *et al*., 1997; DiBella, 1999; MORI, 2001; Vetenskap & Allmänhet, 2003; Andrews *et al*., 2005; Holliman & Jensen, 2009; Kreimer *et al*., 2011; Searle, 2011; Dudo *et al*., 2014; Gustafsson, 2014; TNS-BMRB, 2015; Flaherty, 2016). These findings, both from the literature and the current study, underline the influence of intrinsic rewards in motivating scientists towards public engagement.

This finding, namely that scientists invest time and energy in public science engagement because of the way it makes them feel about themselves and their work was significant, since it explained why some scientists invest time and energy in public engagement, even when they do not perceive tangible benefits. Moreover, these findings contradicted the commonly held perception in the culture of science of scientists as dispassionate and emotionless experts. The influence of these positive emotions that scientists experience while engaging with the public and how it may be linked to their personal values and personalities are not well understood and have seldom been reported in science communication literature.

Based on scientists' reflections on the rewards they experienced as a result of engaging with the public, it is clear that both types of rewards, concrete and abstract, contribute towards motivating scientists to engage.

6.2.2.10. Scientists' perceptions of risks associated with public science communication

In line with their international counterparts (Jacobson *et al*., 2004; Martín-Sempere *et al*., 2008; Searle, 2011; Ecklund *et al*., 2012; Watermeyer, 2015a) (as summarised in 3.3.10), participating scientists saw some level of reputational and/or career risk in going public with their work and feared some of the repercussions of becoming publicly visible. These risks were typically attached to certain practices in public communication of science, and were mostly associated with media and social media activity. Typical risks included the risk of negative comments from peers that are associated with reputational or credibility risks. Based on their years of communication experience, they were, however, able to implement specific actions in order to minimise the chances of being misunderstood, misinterpreted or misquoted. Having learned to manage these risks, visible scientists in the current study did not shy away from participation in public communication, except (for some) when it came to social media, where they did not feel confident that they could use this communication tool without exposing themselves to high levels of risk.

Based on their own experiences and observations of others, the perception that public communication harbours potential risk is a reality for most scientists, and it does influence their own behaviour when it comes to public science communication.

6.2.3. Contextual factors

6.2.3.1. The effect of national context

The characteristics of the South African context emerged as one of the most distinctive drivers that influenced the communication behaviour of local scientists, in comparison with their global peers (as summarised in 3.4.1). My findings regarding specific factors in the local context which influenced scientists' engagement with society, were in line with scholarly views that science communication is shaped by cultural variances and societal influences, and that it therefore differs between countries and regions (Du Plessis, 2008; Peters, 2013; Bucchi & Trench, 2014; Medin & Bang, 2014; Crettaz Von Roten & Goastellec, 2015). Accordingly, the current study highlighted the defining effect of several factors that were closely associated with the South African context (and particularly its socio-political climate) and provided new insights into the communication behaviour of local scientists.

For visible scientists in South Africa, their participation in public science engagement frequently had political roots, dating back to their involvement as political and social activists during the apartheid era. These scientists became familiar with the mass media and controversial public debates during turbulent times in the history of the country. They continued to draw on those experiences in terms of their participation in public communication, including advocacy, and they were not easily dissuaded from public communication by the prospect of peer criticism.

In contrast with the situation in South Africa prior to 1994, scientists were cognisant of the political support for science (and science communication) brought about by the new democratic dispensation in South Africa. This inspired them to contribute to the democratisation of science and to play a role in promoting evidence-based, informed decision-making. Based on their desire for policy impact, scientists considered policymakers as one of the most important audience groups with whom they needed to engage.

Many visible scientists were motivated by a perceived public demand for factual information about science, and the associated need to counter misinformation and pseudoscience in the public sphere. In this regard, the Aids denial by former South African president Thabo Mbeki (South African President from 1999 to 2008) was a particularly thorny issue for local scientists. It turned out to be a turning point for several participants in the current study in terms of their realisation that they had to defend science in the public arena.

In present-day South Africa, many participating scientists said that they were moved by prevalent socio-economic challenges in the country, particularly poverty and disease, to invest time and effort in public communication activities. Confronted by the hardships suffered by millions of fellow South Africans, participating scientists acknowledged that they were generally aware that they occupy a privileged position in society. Consequently, they perceived a strong moral duty to use science communication as a tool to help create a more equitable society. They emphasised the importance of providing credible and timely scientific information to the public, and the right of society to have access to new knowledge. Motivated by a conviction that access to knowledge about science could help to improve people's lives and economic prospects, they perceived a particular urgency in making relevant new knowledge accessible to poor people and rural communities. Some scientists were particularly driven by a desire to combat misinformation about diseases such as TB and HIV/Aids, since they were aware of how unscrupulous operators take advantage of vulnerable and desperate people that may not be able to distinguish between credible advice and health scams, and the associated health and financial implications.

Given the high levels of corruption in public institutions that are consistently reported in local media, participating scientists were concerned about the taxpayers' continued support for science. As a result, they were keen to demonstrate the value and outcomes of the money spent on research. They hoped that public communication of science would make the benefits of research visible to society in order to secure ongoing public interest and goodwill.

Living and working in South Africa, natural scientists (particularly biologists and palaeontologists) were inspired by the biodiversity and rich fossil heritage of the country to share their findings with fellow citizens. Equally, social scientists were enthused by the dynamic societal landscape towards pro-active public engagement.

These factors, as discussed above, shed new light on the influences that shape the public communication behaviour of scientists, particularly in developing-country settings and diverse societal contexts. They confirmed that the South African context influences scientists' interest and willingness to participate in public science communication activities, as a result of country-specific challenges and opportunities that characterise the local science communication terrain. Specific stimuli in the local context made South African researchers more receptive towards the idea of sharing their science with lay audiences, and compelled them towards participating in public debate. These stimuli range from socio-economic challenges (poverty and disease) to the unique environment for doing research (the southern skies, fossil heritage and biodiversity) in South Africa.

6.2.3.2. The effect of institutional environment

The distribution of participating scientists in South Africa, with more than half of them working at just four universities, suggests that their institutional environments contributed to their public visibility. The science communication literature confirms that the culture and support structures at the research organisations where scientists work, have a direct effect on their participation in public science communication (e.g. Van der Auweraert, 2008; Edge *et al*., 2011; Bauer & Jensen, 2011; Searle, 2011; Dudo, 2013; Entradas & Bauer, 2016) (summarised in 3.4.2). However, many scientists perceive that their organisations are indifferent towards their public engagement activities and offer very little support (Gasgoigne & Metcalfe, 1987; Searle, 2011). In general, scientists are more motivated to get involved in public engagement if they feel that these activities are recognised and valued in their immediate work environments, while uncertainty about the institutional acceptance of public communication discourages their participation (Andrews *et al*., 2005; Smith *et al*., 2013).

Searle (2011) highlights a gap between institutional rhetoric about the importance of public science communication and the policy and institutional climate in Australia, while Nhamo (2013) agrees that, in South Africa, universities emphasise the importance of community engagement and outreach, but fail to invest in these activities. These views were also supported by the interview data that resulted from the current study, with participating South African scientists mostly perceiving a lack of institutional credit and backing for public science communication. While this did not dissuade them from public engagement, they nevertheless indicated that they would welcome more encouragement and support, and remarked that institutional recognition would increase their involvement.

During the interviews, visible scientists did mention some examples of institutional awards and incentives for public science communication, indicating a gradual shift in institutional culture towards more support for public science engagement. For example, at UCT, 'social responsiveness' became one of the categories whereby academics are evaluated and the university also offers an annual social engagement award. The University of the Witwatersrand has an 'Academic Citizenship Award' to encourage and recognise public science engagement. In 2016, the MRC introduced a new performance indicator, namely being 'A Good MRC Citizen' as a way to encourage and recognise public science engagement.

In terms of institutional support for public science communication, several visible scientists were in favour of having dedicated communication specialists within research teams, who were able to identify and respond pro-actively to public communication opportunities, as well as design and implement professional communication strategies. Visible scientists in the current study commented at length about the value and virtues of being able to call on the support of trusted professional communicators, and elaborated about how a good relationship with these institutional communicators enhanced their communication efforts. Accordingly, scientists in other countries have expressed the wish for a dedicated communication unit to take charge of public science communication responsibilities (e.g. Nielsen *et al*., 2007).

However, while the roles of intermediaries and mediators in public science communication are established and recognised (e.g. Rowe & Brass, 2011; Bultitude *et al*., 2012; Dudo, 2015; Landrum, 2017), the delegation of public communication duties to a professional communicator could diminish the roles of scientists as the primary public experts. Furthermore, the appointment of communication professionals within research institutions and research teams has been shown to increase the prominence of media criteria in science (Peters *et al*., 2008; Rödder, 2011; Ivanova *et al*., 2013), thereby presenting risks of medialisation of science within research institutions (Weingart, 2002; Rödder, 2009; Marcinkowski & Kohring, 2014). Other unintended results of allowing communication professionals, rather than scientists themselves, to take charge of public communication could include problematic science PR campaigns (e.g. Williams & Gajevic, 2012; Weingart & Guenther, 2016) and potentially unethical PR practices that may involve distortions and hype in science press releases that lead to exaggerated and potentially misleading news reporting (e.g. Sumner *et al*., 2014; Weingart, 2017a). Consequently, a new focus on responsible public communication of science is emerging, which emphasises open, honest and ethical dialogue between science and society (Nisbet & Scheufele, 2009; Dahlstrom & Ho, 2012; German National Academy of Sciences, 2016; Medvecky & Leach, 2017).

In line with international trends (Peters *et al*., 2008b; Dudo *et al*., 2014; Marcinkowski & Kohring, 2014), there were some indications from the current study that PR pressures in research environments were, at least to an extent, beginning to shape scientists' communication behaviour. Many of the respondents referred to growing demands from their institutions and/or funders to disseminate their research in the public arena, and some interviewees felt that they owed a duty towards their universities in terms of promoting the image and profile of the institution.

Interestingly, participants were not aware of any institutional policies or approval processes that would prevent them from engaging with external audiences. In fact, they were mostly of the opinion that their institutions did not have a policy pertinent to public science engagement. Scientists' uncertainty about institutional policies regarding public communication has been highlighted before in studies by Gascoigne and Metcalfe (1997), Holland (1999) and Ndlovu *et al*. (2016).

Data from the interviews conducted for this study, confirmed that the cultures and policies in environments where scientists worked were pertinent influencers of their public engagement behaviour, which played a key role in shaping scientists' engagement with external audiences. In particular, support from professional communicators was considered an important contributor to scientists' ability to engage with external audiences.

Overall, in the current study, institutional culture was seen as an impediment to public science communication, rather than as an incentive. This suggests that, for the most part, institutional drivers were not yet dominant stimuli of public science communication, as has been reported for other countries (Marcinkowski & Kohring, 2014). This finding implies that changes in institutional culture and policies, and a more formal recognition of and reward for these activities, could have a significant effect on the public engagement behaviour of scientists in South Africa. This would require the implementation of communication-supportive institutional policies, as well as investment in evaluation systems, including relevant performance indicators that could evaluate scientists' contribution to public communication as part of a scholarly career meaningfully. However, while institutional policies and funding instruments are recognised as important instruments to stimulate public science engagement, the additional demands made on scientists' time are cause for concern, since these activities may conflict with the traditional scholarly roles of scientists, as has also been shown by The Royal Society (2006) and Casini and Neresini (2012).

6.2.3.3. The effect of evaluation

Despite a growing recognition of public science engagement (or community engagement) as a key contributor to so-called 'third-stream' activities at universities, participating scientists did not perceive that these activities were high on institutional agendas. These views corresponded with earlier research findings that public communication is widely perceived as inconsequential in measuring scientific performance (Shanley & Lopez, 2009), as well as the opinion that public science communication in South Africa remains neglected in terms of institutional policy, commitment and support (South African Council on Higher Education, Nhamo, 2013) and is consequently rarely evaluated formally.

Research shows that, when institutions do not evaluate public science communication efforts, it signals to the scientists who work there that these activities are not a high priority (Neresini & Pellegrini; 2008; Neresini & Bucchi, 2011) and it is therefore unlikely that they will invest in their own evaluation of their public communication efforts (see 3.4.3). Data from this study confirmed that researchers, even those who were highly visible in society, generally gave little thought to evaluating their public communication activities and mostly lacked expertise on how to plan for and implement monitoring and evaluation. A general lack of expertise to evaluate science communication meaningfully is not unique to South Africa, and has been demonstrated and discussed more broadly (Rowe & Frewer, 2000, 2004; Rowe *et al*., 2004; Neresini & Bucchi, 2011).

Some scholars make a strong case for formal evaluation of scientists' public engagement work, associated with relevant incentives for those who perform, as a way to legitimise and recognise these activities (Neresini & Pellegrini, 2008; Neresini & Bucchi, 2011; Druckman, 2015; Grand *et al*., 2015). Moreover, studies also show that some scientists would not be in favour of formal evaluations of their public communication activities, preferring to have autonomy in their choices regarding public engagement (Dudo *et al*., 2014; Grand *et al*., 2015; Chikoore *et al*., 2016). The majority of visible scientists interviewed in the current study concurred with the latter opinion, i.e.

they were not in favour of making public communication of science a compulsory part of research performance measurements and/or grant funding, or a mandatory part of a scholarly career.

Bauer and Jensen (2011:10) highlight another potentially counterproductive effect of formal evaluation of scientists' engagement activities, namely that the nature of these activities may change when they are no longer undertaken on a voluntary basis. The intrinsic motivations for public communication (fun, personal reward) then become "crowded-out by institutional incentives and defined duties that are set by institutional commitments". As a result, participating in public engagement may become another box that scientists have to tick, and meaningless 'pseudo engagement' activities may proliferate. In such an over-managed research culture, researchers who are forced to participate in public engagement might do so for the wrong reasons (Burchell, 2015).

A related debate in the science communication arena concerns the issue of whether scientists' participation in social media (in particular) could (and should) be measured as part of their academic and societal impact. Findings about the academic and social returns generated by Twitter and similar social media networks have resulted in proposals that these activities should be included when academic impact is measured (Eysenbach, 2011; Shuai, Pepe & Bollen, 2012). Priem *et al*. (2012) propose that altmetrics[95] could be a useful alternative to measure societal impact of research, recommending its use alongside citation-based measures, while Bornmann (2014) agrees that altmetrics could offer a useful way to measure the level of public engagement with research. A 2016 report from the American Sociological Association recommends that public communication, including social media activity, should be taken into account to judge the impact of academics, as well as to recognise and reward high-quality public science communication (McCall *et al*., 2016). The report is explicit about the need to assess the rigour, quality and impact of online communication and suggests relevant evaluation criteria. While social media activity is rarely formally considered in the evaluation of scholarly outputs, some scholars believe that it is already accepted as a component of academic activity (Marcinkowski & Kohring, 2014) and it plays a role when it comes to academic appointments and related decisions (Flaherty, 2016).

Notably, major research funders around the world are beginning to include broader societal impact as one of the measurements when evaluating scientists' outputs (Kamenetzky, 2013; Nadkarni & Stasch, 2013). The Research Excellence Framework that was introduced in the United Kingdom in 2014 includes research impact as one of the criteria that determines science funding (Research Councils UK, 2014), with public science engagement recognised as an example of such impact. Similarly, the NSF, one of the largest research funders in the world, includes non-traditional research outputs, which could include social media activity, when funding applications and progress reports are assessed (Piwowar, 2013).

[95] Altmetrics is a term to describe "web-based metrics for the impact of publications and other scholarly material by using data from social media platforms (e.g. Twitter or Mendeley)" (Bornmann, 2014).

The visible scientists I interviewed were keenly aware of these changes in science policies and funding instruments that have started to emphasise social impact, and they expected changes in the way public science communication activities would be documented, monitored and evaluated in future.

Despite trends towards integrating societal impact into evaluations of scientists' performance, it is widely recognised that it could be problematic to measure the societal impact of public science communication. This is because the desired societal effects of public science communication, such as an informed public or a growing scientific workforce, typically manifest over a long time period, making it nearly impossible to predict these impacts upfront or to trace them afterwards. Jensen (2014) highlights some of the challenges of effective and meaningful evaluation of public science communication activities, while King, Steiner, Hobson, Robinson and Clipson (2015) show the difficulties of demonstrating impact in informal science learning environments amidst increasing demands for evidence of impact coming from institutions and funders. Grand *et al*. (2015), Terämä *et al*. (2016), and Holliman and Warren (2017) elaborate on the challenges of including an assessment of societal impact in the evaluation of researchers, but also reflect on the positive spin-offs of such policies in terms of their potential to stimulate engaged scholarship.

Consequently, including the impact of public science communication as one of the measurements in the evaluation of scientists and research teams is expected to be challenging and difficult to operationalise. Furthermore, scholars warn about the potentially damaging medialisation effects that are expected to occur, should scientists be recognised and rewarded for their communication efforts, rather than for the quality of their science (Weingart, 2002; Rödder, 2009; Marcinkowski & Kohring, 2014).

6.2.3.4. Medialisation effects

Despite the view that medialisation and the associated escalation of professional PR practices in research organisations may be influencing the way scientists communicate in some other countries (Weingart, 1997, 2002; Rödder, 2009; Marcinkowski & Kohring, 2014) (as summarised in 3.4.4), the current study provided limited evidence that local scientists are influenced by an increased orientation towards the media and/or institutional PR pressures. However, in the case of the two most visible scientists (Professor Lee Berger and Professor Tim Noakes) there were some signals of medialisation in the way they partnered with the media when they planned, executed and communicated their research. Several other respondents also indicated that they were aware of growing expectations from employers and funders to engage more visibly with society, and that they expected these demands to grow in future.

Medialisation effects could therefore become more prominent if South African research institutions follow the international trend (Kohring *et al*., 2013) to invest more heavily in professional science PR as a way to build institutional reputations and compete for public and political support and funding. Furthermore, participating scientists were clearly aware of the threat of hyping up science findings in order to attract media attention. Consequently, it would be wise to be aware of the potential effect of medialisation and how it could shape the (future) communication behaviour of top scientists at leading research institutions in South Africa.

6.3. Potential policy implications

If the intention is to advance public science engagement, which is a stated aim of the South African government (DST, 2014), several findings from the current study could inform future policies in this regard. These potential implications and applications are briefly outlined below.

6.3.1. Black scientists as role models

Findings about the influence of population group as a factor that affects public science communication behaviour were new and unique to the current study and pointed towards the potential of young, black scientists (particularly young, black women in science) to act as catalysts in promoting constructive engagements between science and South African publics. These considerations are particularly pertinent in South Africa where black scientists are still comparatively invisible in the public sphere (according to the findings from this study) and encouraging black learners to consider careers in science is an important policy imperative (DST, 2014). These findings point towards the need to identify young black scientists who are potential role models in science.

6.3.2. Visible scientists as communication mentors

The fact that visible scientists in the current study were positive and pro-active about involving junior colleagues and students in public engagement means that high-profile scientists are (or could become) facilitators and catalysts in the process of broadening the base of scientists that are actively involved in public engagement. An important policy implication is that senior, visible scientists, who have extensive experience of public engagement, are likely to be willing, if called upon by policy makers, to act as mentors for young scientists who are interested to increase their engagement with society.

6.3.3. Responsible use of social media

Scientists' concerns over the potentially negative consequences of using social media to engage with public audiences, as well as their self-confessed lack of social media skills, were evident in the current study. Given the widespread recognition that digital media environments are strengthening as primary sources of science news and key tools for societal dialogue (Anderson *et al*., 2010; Brossard, 2013; Brossard & Scheufele, 2013; Liang *et al*., 2014; Peters *et al*., 2014; Flaherty, 2016), it becomes relevant to consider how South African scientists could be helped to benefit from new opportunities presented by digital science engagement, while avoiding or minimising its potential perils. In this regard, a recent report by the German National Academy of Sciences (2017) offers useful considerations. It acknowledges the exceptional rate and impact of digitisation of the communication landscape on public perceptions of science, and highlights the opportunities and risks presented by these new communication formats. While scientists are encouraged to participate in public debate via social media channels, the report accentuates the importance of adhering to principles of integrity and responsible use. Amongst its recommendations, this report calls for stronger regulation and a quality-oriented code of conduct for science communication via the Internet, and particularly via social media.

6.3.4. Communication-enabling institutions

While it is impossible to change the background factors that influence scientists' engagement behaviour (i.e. age, gender, population group and research field) it would be possible to create incentives and rewards that could support scientists' public communication efforts. The current study highlighted the prominent influence of institutional environments on scientists' attitudes towards public communication. This implies that the potential levers to stimulate scientists' involvement are mainly located in the institutional environments where they work, which agrees with the finding by Edge *et al*. (2011) that institutional factors have an important and defining influence on the communication behaviour of scientists.

Institutions that wish to increase the involvement of their academic staff members in public science engagement could consider these steps towards creating a communication-supportive institutional environment, as suggested by Markowitz (2017) at the 2017 AAAS Annual Meeting.

- Create platforms and opportunities for scientists to engage with public audiences.
- Institutionalise and normalise public science communication as part of what scientists do and review it as part of what constitutes success in science.
- Recognise and publicise the public engagement work done by research staff.
- Protect scientists who step out into public life, especially when they may fear repercussions (or even attacks) from anti-science lobby groups.
- Celebrate the impact of public science engagement to showcase best practice, recognise individuals and motivate others towards involvement.

However, when implementing such recommendations, it is important to do it in a way that will reward and support scientists who make an effort to engage with society, without necessarily penalising scientists who prefer not to take part. It is furthermore essential to ensure ethical science communication that protects the autonomy and integrity of science. In this regard, a recent report from the German National Science Academy (2017) highlights the need to develop sensitive indicators that would encourage responsible communicative behaviour on the part of research organisations and scientists. Amongst other recommendations, this report calls for a distinction between fact-based science communication (not primarily guided by particular interests) and institutional communication about science (primarily guided by reputation-building interests).

6.3.5. Responsible science PR

The current study indicated that, to date, the influence of science PR practices on science communication practice in higher education institutions has been limited. However, interviewees were aware of growing institutional demands for public communication and they were also in favour of closer working relationships with professional science communicators. Consequently, the role of science PR is expected to expand.

Despite concerns over and criticisms of public relations practices in scientific institutions (Rödder *et al*., 2012; Kohring *et al*., 2013; Marcinkowski & Kohring, 2014; Weingart, 2017a), some science communication scholars and practitioners acknowledge the constructive role that public relations could play in research institutions (Cilliers, 2001; Autzen, 2014; Borchelt & Nielsen, 2014; Shipman, 2014, 2015).

Recognising that research institutions will continue to invest in public relations activities, the German National Academy of Sciences (2016) has drawn up a list of guidelines for responsible and ethical conduct in science PR that could provide a relevant starting point to guide PR practices within research institutions. These guidelines encourage research organisations and scientists to engage with the media, but emphasise open and honest communication, including the acknowledgements of the limits of science, as well as potential risks and uncertainties in new findings. It furthermore encourages scientists to speak about themselves, their motivations and their work, to communicate according to the information needs of specific target groups, and to use accessible tools and channels, and easily understandable language.

6.3.6. Science communication planning

Despite their positive view of public communication, the majority of the scientists I interviewed for this study conceded that they were not pro-active in this regard, but rather responded to communication opportunities that crossed their paths. This could be a potential point of concern, since, without forward planning, public science communication is likely to remain a peripheral activity and many opportunities for constructive engagement with society are likely to be missed.

Grand *et al.* (2015) highlight the value of embedding strategic communication planning within research. Besley and Dudo (2017) explain the difference between strategic and non-strategic science communication. Strategic communication involves careful consideration of communication goals, followed by the development of plans for how to achieve such goals in ways that are consistent with the principles that the scientific community values (e.g., honesty, transparency, inclusiveness). Non-strategic communication takes place in an ad-hoc fashion and has limited potential to help realize stated goals, and is considered wasteful and potentially damaging. Dudo, Besley and Yuan (2017) adds further evidence about the value of a strategic approach to science communication in order to select realistic and ethical communication strategies, thereby enhancing the efficacy of science communication efforts.

6.3.7. The science of science communication

In a global communication arena increasingly characterised by populism, fake news, anti-science lobbies, and even a perceived war on science (Achenbach, 2015), scientists' concerns over public trust in science are understandable. Scientists typically believe that these problems could be addressed by giving people more information (i.e. the 'facts' or the 'truth') about a specific issue

(Davies, 2008; Campbell, 2017; Zimmerman, 2017). Similarly, in the current study, interviewees emphasised the importance of giving people updated and factual information about science as a way to combat pseudoscience and misinformation in the public sphere.

However, recent insights from a broad research field known as the 'science of science communication' (Fischhoff & Scheufele, 2013; National Academy of Sciences, 2014; Jamieson, Kahan & Scheufele, 2017) show that an emphasis on the one-way transmission of scientific facts, without recognising the social and psychological nature of public science communication, might be counterproductive. The National Academies of Sciences, Engineering and Medicine (2017) have put forward a research agenda for the science of science communication that could inform relevant research in the local context.

6.4. Study limitations

A few limitations of the current study should be noted.

- In order to identify visible scientists in South Africa, only experts working at the science-media interface were considered for inclusion on the science-media panel. Of the 63 individuals approached, only 46 responded to the request, and the respondent group was predominantly white. In addition, these experts were only asked to name between five and ten scientists. There might be other respondent groups to consider that could extend the number of visible scientists in South Africa. Furthermore, only the names of visible scientists were requested from the science-media panel (i.e. I did not ask them to explain why they regarded these scientists as being publicly visible).
- While 211 visible scientists were identified, only 30 of them were interviewed. Of the 30 interviews, only 26 were done face-to-face, while time and cost limitations necessitated doing the remaining four interviews telephonically. Most of the interviewees could devote a maximum of one hour to the interview, but some interviews went on for longer, allowing deeper and more exploratory discussions. Only 24 of the 30 the interviewees responded to my request for validating their interview data as quoted in this dissertation.
- Since my study was qualitative in nature, it was only possible to explore the influence of the factors one by one in order to determine whether and how they influenced scientists' public communication behaviour, but it was not possible to explore how these factors influence one another. For that, a quantitative study would be required.
- It should be noted that a type of response bias known as 'social desirability bias' could have influenced the data generated by the qualitative interviews. Social desirability bias (Fisher, 1993) refers to the tendency of to project a favourable image of themselves, causing them to provide answers that would put themselves in a good light and a tendency to avoid sensitive topics. Consquently, they may over-report behaviours perceived to be positive or desirable, while ender-reporting behaviours perceived to be negative or undesirable.
- Since the study focused on scientists who were identified as being publicly visible, they represent, in some sense, 'the converted' – i.e. those scientists who are supportive of public

science engagement and are typically keen to engage with audiences outside the academic environment. Consequently, the views of scientists who are critical or negative towards public science engagement and who avoid these activities were not captured by this study.

- Lastly, it is important to note that the current study focused on the influencing factors as identified in the theoretical foundation and literature review that supported this study. It is possible that other factors may also play a role. Interviewees were not asked whether anything else influenced their participation in public science communication.

6.5. Suggestions for future research

The current study highlighted potential avenues for further study. Quantitative research to determine the relative weight of the influencing factors discussed in the current study could shed further light on their proportional influence on the public communication behaviour of visible scientists, as well as the associations (relationships) between these factors. In particular, a better understanding of the communication behaviour of high-profile scientists that have endured intense public and peer scrutiny (as was the case with the two most visible scientists in this study) will further aid our understanding of the factors that influence and shape the interaction between scientists and their diverse publics in a country like South Africa, and may clarify how medialisation effects are influencing the work of these highly visible scientists.

It is a commonly held view that one of the reasons why public science communication should not be demanded of all scientists is that some scientists are simply not suited for a public stage because they are shy or introverted. Interestingly though, several of the scientists I interviewed adamantly insisted that they were introverts. I was able to locate a few studies and essays that touched on different personality types amongst scientists (Goodell, 1975; Van der Auweraert, 2008; Searle, 2011; Tsfati *et al.*, 2011; Weiler *et al.*, 2012; Harkness, 2015; Rosen, 2016), but I could not locate studies that explicitly explored the link between personality type and public communication behaviour. These questions, namely how scientists' personality types affect their public engagement behaviour, and how introverted scientists overcome communication barriers, could therefore be fruitful topics for further study.

Scientists' use of social media is a topic that currently attracts considerable attention from science communication scholars. This topic has not yet been explored in the local context and could provide multiple possibilities for ongoing future research. At the same time, we need a better understanding of the status of and changes within mainstream science journalism in the country, and the interplay between legacy media and digital media when it comes to public science engagement.

Given the challenges regarding meaningful evaluation of scientists' public communication activities, further research into the feasibility and desirability of measuring, recognising and rewarding these activities is recommended, taking note of current work that has already been done in terms of developing suitable and meaningful indicators of public science engagement, and applying these indicators appropriately and sensitively.

Lastly, given the increasingly competitive nature of the higher education landscape, further research into the nature and influence of institutional science communication (including science PR), as well as its probably unintended but potentially dysfunctional consequences, as practiced within South African universities and related organisations such as science councils, is recommended.

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Appendices

Appendix 1: Chronological list of research articles (1991 – 2016[96])

Title	Method	Country	Key finding(s)	Citation
1. Scientists' Reasons for Consenting to Mass Media Interviews: A National Survey	Mail survey completed by 255 scientists	United States	Most scientists are willing to do interviews, driven by the objective to educate the public and generate interest in their own research. Public education is seen as a respectable endeavour, while seeking publicity for monetary gain is not.	DiBella, Ferri & Padderud, 1991
2. Incentives and impediments to scientists communicating through the media	Mail survey completed by 92 scientists, & 10 focus groups	Australia	Australian scientists believe that media coverage of their work is important and delivers significant benefits, but feel that their organisations are indifferent to it and offer little support.	Gascoigne & Metcalfe, 1997
3. Scientists and the public understanding of science	Interviews with 168 scientists; print and phone survey	United Kingdom	Almost all scientists enjoy participating in public outreach and, despite time constraints, perceive several benefits, including improved communication skills, enhanced morale and team building.	Pearson, Pringle & Thomas, 1997
4. The Media and Public Understanding of Biotechnology: A Survey of Scientists and Journalists	Interviews with 30 scientists in the field of biotechnology	United Kingdom	Scientists agree that media play an important role in informing the public about biotechnology. Scientists – more often than journalists – perceive media coverage of biotechnology as sensational, dramatic and speculative, with too much emphasis on risks.	Gunter, Kinderlerer & Beyleveld, 1999
5. Factors and Strategies that Influence Faculty Involvement in Public Service	Review of earlier studies	United States	A solid understanding of the factors that motivate scientists to engage in public service could support effective supporting strategies. Consistency in the way public service is defined and supported is of key importance for faculty members to view public service as a legitimate component of scholarly work.	Holland, 1999
6. The role of scientists in public debate	Online survey of 1 540 scientists, followed by 112 interviews	United Kingdom	Most scientists see benefit in improved public understanding of science and believe it is their duty to communicate their research, but are constrained by the demands of their jobs and lack of skills. Scientists welcome incentives such as funding and media training, as well as institutional encouragement, to support public engagement.	MORI, 2001

[96] The findings of these studies – published over a period of 25 years between 1991 and 2016 – are discussed in detail, but some earlier studies are also included in my literature review. Most notably, I have used the 1975 study of visible scientists by Rae Goodell as an important reference point for my own research, Goodell (1975, 1977).

Title	Method	Country	Key finding(s)	Citation
7. The participation of scientists in public understanding of science activities: the policy and practice of the UK Research Councils	Comparative study of the policies and practices of five research councils	United Kingdom	There is a gap between policy and practice at United Kingdom research councils regarding public understanding of science, which raises questions about the desirability and feasibility of the idea that all scientists should be involved in outreach activities.	Pearson, 2001
8. 'Them and us': Scientists and the media — attitudes and experiences	Mail survey of 100 researchers	South Africa	Scientists need allocated time, training and incentives in order to be able to communicate their research via the mass media.	Gething, 2003
9. How researchers view public and science	Qualitative interviews with 400 scientists	Sweden	Only half of researchers believe that people are generally interested in and supportive of research. In spite of this, most scientists feel that the public trusts researchers. Scientists generally value dialogue with the public and even see it as an obligation to engage. Some report that public engagement provides new perspectives on their own work, but others regard public dialogue as too time-consuming.	Vetenskap & Allmänhet, 2003
10. Organizational Factors that Influence University-Based Researchers' Engagement in Knowledge Transfer Activities	Review article	Canada	Academics perceive that outreach is not widely accepted as a legitimate form of scholarship. They fear that the time and energy spent on outreach will not count when they are judged for promotion and tenure. Key outreach barriers include lack of rewards and incentives, low status of outreach, lack of funding and support, and confidentiality concerns.	Jacobson, Butterill & Goering, 2004
11. Scientists and public outreach: Participation, motivations, and impediments	Online survey completed by 23 students and staff, plus nine interviews	United States	Scientists participate in outreach for similar reasons, but levels of involvement and the types of activities vary by career stage, job type, and gender. The strongest motivating factors are a desire to contribute and the enjoyment they get from outreach. Older scientists are motivated by the pleasure of sharing knowledge, while junior researchers enjoy the positive responses of students.	Andrews, Weaver, Hanley, Shamatha & Melton, 2005
12. Coming down from the ivory tower? Academics' civic and economic engagement with the community	Online survey completed by 830 academics, plus 80 interviews	United Kingdom	Academics are committed to engagement and interaction with their communities, despite the fact that it is often accomplished under sub-ideal circumstances. The vast majority believe that public engagement is important and are involved. Scientists engage out of a sense of duty, but also to recruit students and secure funding. Constraints include time pressures, lack of experience and lack of academic prestige.	Bond & Paterson, 2005

Title	Method	Country	Key finding(s)	Citation
13. Popular science publishing and contributions to public discourse among university faculty	Two mail surveys of researchers: 1 590 responses (1992); 1 937 (2001)	Norway	Prolific scientists are more active in publishing for a lay public compared to less productive colleagues. Also, a small number of academic staff members account for a disproportionate number of popular articles.	Kyvik, 2005
14. Geneticists' views on science policy formation and public outreach	Interviews with 20 senior scientists	United States	Scientists accept public engagement as a key responsibility and are adamant about the need to communicate findings to the public in order to improve public understanding of science. Scientists should be more actively involved in outreach, but feel ill-equipped and unsupported by their peers and institutions to pursue these activities. Scientific societies should play a larger role as a link between scientists and the public than is currently the case.	Mathews, Kalfoglou & Hudson, 2005
15. Trying to relate: Media Relations Training Needs of Agricultural Scientists	Online survey completed by 62 scientists	United States	Researchers view national news coverage more negatively than the media coverage of local agriculture and science. They perceive coverage of general science topics more favourably than the coverage of agriculture. They are confident in their own ability to deal with the media, with differences according to gender and age.	Ruth, Lundy, Telg & Irani, 2005
16. It Takes Two: Public Understanding of Agricultural Science and Agricultural Scientists' Understanding of the Public	Online survey completed by 62 researchers	United States	Respondents agree that it is their responsibility to help people understand agricultural science, but they are not convinced that their colleagues share a conviction of this responsibility. They are willing to work with journalists and undergo media training, as long as this would benefit them personally, or benefit their institutions.	Lundy, Ruth, Telg & Irani, 2006
17. Assessing Michigan State University's Efforts to Embed Engagement across the Institution: Findings and Challenges	Interviews with 26 faculty members	United States	Most scientists view outreach and engagement as an additional task that they perform for the public good, rather than as an official responsibility. Disciplinary boundaries influence how faculty members define and value outreach significantly. Multiple pressures, including the lack of institutional and peer support, inhibit outreach activities. To increase the amount and effectiveness of outreach work, university reward systems must recognise outreach as part of academic work.	Lunsford, Church & Zimmerman, 2006
18. Scientists' view about communication in the Italian context	Survey of 305 scientists	Italy	Researchers view communication as important and useful, but feel that they lack the confidence and skills to do it effectively. They have particularly high expectations of media interactions.	Pitrelli, Brunelli & Murelli, 2006

Title	Method	Country	Key finding(s)	Citation
19. Factors affecting science communication: A survey of scientists and engineers	Online survey completed by 1 485 scientists and 41 interviews	United Kingdom	Scientists are generally willing to take part in outreach, with 75% already involved and about half wanting to spend more time on it. Most agree that scientists have a moral duty to engage with the public. The biggest constraint is that it is not seen as an important part of research, while time pressures are also a key barrier. Age and seniority influence engagement activity. Some scientists say that outreach helps them become better researchers. Funding, manager support and opportunities encourage participation. Funders are aware that research grants provide a powerful tool for stimulating public engagement, but are concerned about making additional demands on researchers.	The Royal Society, 2006
20. European Research in the Media: the Researcher's point of view	Telephone interviews with 100 scientists	EU member states	Relationships between scientists and the media are more positive than expected. Researchers recognise the need for scientists to be open towards the media and report that the Internet is helping them to communicate science effectively to public audiences. Scientists are motivated to communicate by feelings of personal accountability and the desire to inform the taxpayers who indirectly supported their research. They want to correct or avoid misconceptions of science, particularly in the light of their fear that scientific information is sensationalised if not provided by trustworthy sources.	European Commission, 2007
21. Turning Sexual Science into News: Sex Research and the Media	Online survey completed by 94 researchers, supplemented by focus groups	United States	Sex researchers and journalists share a common goal, namely to provide information that will serve the public. While recognising the different core values that govern scientists and journalists, an increased understanding of one another's perspectives could facilitate mutually beneficial collaboration. Researchers would welcome media training, and would like it to be included as part of formal graduate or professional education.	McBride, Sanders, Janssen, Grabe, Bass, Sparks, Brown & Heiman, 2007
22. Scientists and science communication: A Danish survey	Online survey completed by 1 038 natural scientists and engineers from six universities	Denmark	Scientists and engineers are keen to communicate science through the news media, but have mixed feelings about the quality of media coverage. They are keen to use other channels to reach diverse audiences. More than half are willing to allocate up to 2% of their research funding to science communication. Nearly half of the respondents agree that scientists themselves ought to take responsibility for science communication, but the rest want a separate unit (communication or admin) to take on this role.	Nielsen, Kjaer & Dahlgaard, 2007
23. What factors predict scientists' intentions to participate in public engagement of science activities?	Mail survey completed by 169 academics and students	United Kingdom	Over and above past experience, three factors predict scientists' intentions to participate in public engagement, namely attitude, perceived behavioural control and descriptive norms (whether scientists believe their colleagues participate). Career recognition and time constraints do not significantly predict intentions to engage with the public.	Poliakoff & Webb, 2007

Title	Method	Country	Key finding(s)	Citation
24. *Postmoderne wetenschapscommunicatie: zijn wetenschappers er klaar voor?*[97]	In-depth interviews with 15 researchers	Belgium	Researchers have significantly different visions, attitudes and approaches towards their roles in the production and communication of new knowledge that influence their science communication behaviour. The way in which researchers present their work to the public is strongly influenced by their own perspectives relevant to their research. One-way communication is still dominant, with less evidence of an interactive approach.	Van der Auweraert & Van Woerkum, 2007
25. Experts' understanding of the public: knowledge control in a risk controversy	Survey of 300 aquaculture experts	Canada	Experts' views on lay knowledge and public participation in the science debates range from strongly positive to strongly negative and coincides with issues of control over knowledge. While experts are generally willing to incorporate lay knowledge into their research, they are more critical regarding the way lay publics consume and apply expertise.	Young & Matthews, 2007
26. Constructing Communication: Talking to Scientists About Talking to the Public	Seven focus groups with 3 to 10 participants each	United Kingdom	Scientists predominantly frame science communication as one-way transfer of information that will help to educate public audiences (i.e. a simplistic deficit model). Science communication is often framed negatively – as difficult, dangerous and even impossible, demanding extreme caution to prevent misunderstandings and misuse of information. Scientists who have closer contact with lay publics, reflect more nuanced versions of these publics and interacting with them.	Davies, 2008
27. Scientists who engage with society perform better academically	Content analysis of the annual reports of 11 000 CNRS-funded scientists submitted over three years	France	Scientists active in wider dissemination are also more active academically than other scientists. However, their dissemination activities have almost no impact (positive or negative) on their careers.	Jensen, Rouquier, Kreimer & Croissant, 2008
28. Scientists' motivation to communicate science and technology to the public: Surveying participants at the Madrid Science Fair	Interviews with 167 researchers	Spain	Scientists are mostly motivated to participate in science fairs by the desire to increase the public's interest in and enthusiasm for science, the public's scientific culture, and public awareness and appreciation of science. Senior researchers are motivated by a sense of duty, while personal satisfaction and enjoyment matter more for younger scientists.	Martín-Sempere, Garzón-García & Rey-Rocha, 2008

[97] English translation of Dutch title: Post-modern science communication: Are researchers ready for it?

Title	Method	Country	Key finding(s)	Citation
29. Teaching scientists to interact with the media	Online survey completed by 446 scientists	Australia	Many scientists lack the skills or encouragement to engage the media successfully and may view media interaction as a threat, rather than an opportunity. Scientists, especially those from government institutions, have very limited contact with the media. They view media interviews as an optional activity, and only a third have undergone media training. Most scientists report that their institutions are negative about publicity.	Metcalfe & Gascoigne, 2009
30. Documenting Engagement: Faculty Perspectives on Self-Representation for Promotion and Tenure	Document analysis researchers' reports	United States	Community service work often does not fit in the teaching-research-service triad, and consequently remains unreported and/or undervalued. The work of community-engaged faculty members is critical to realising the civic mission and to changing the culture of higher education institutions. The discourses of work by faculty members and civic engagement need to run parallel to one another, and work towards the common goal of higher education contributing to the public good.	Moore & Ward, 2008
31. Interactions with the mass media	Mail survey with 1 354 responses from researchers	United States, Japan, Germany, United Kingdom and France	Across the countries surveyed, scientist-journalist interactions were more widespread, frequent and smooth than anticipated. Research leaders and research-productive scientists have more contact with the media than others. A researcher's attitude plays a role, as do normative beliefs and institutional reward structures, but these are less important. Despite the positive trend, many scientists (90%) worry about the risk of being misquoted by news journalists; 80% feel that journalists are unpredictable.	Peters, Brossard, De Cheveigne, Dunwoody, Kalfass, Miller & Tsuchida, 2008
32. How university scientists view science communication to the public	Online survey completed by 350 life sciences researchers	United States	Despite lingering barriers that limit public science engagement, university-based researchers are both supportive of others who do outreach and keen to get more involved themselves.	Sturzenegger-Varvayanis, Eosco, Ball, Lee, Halpern & Lewenstein, 2008
33. Health researchers' attitudes towards public involvement in health research	In-depth interviews with 15 health researchers	United Kingdom	Researchers generally agree with the moral and political reasons for including the public in health research and see the value of public participation. However, many feel hesitant and uncomfortable about this new way of doing research.	Thompson, Barber, Ward, Boote, Cooper, Armitage & Jones, 2009

Title	Method	Country	Key finding(s)	Citation
34. *De onderzoeker als communicator: Een kwalitatief en verkennend onderzoek naar de determinanten van wetenschaps-communicatiegedrag*[98]	Interviews with 15 researchers	Belgium	In terms of their involvement in public communication, scientists are either highly engaged, moderately engaged or not engaged at all. They display diverse approaches and selectivity towards science communication, with greater emphasis on transmission of knowledge than interaction with the public. Most scientists have good intentions, but lack the skills and experience to initiate and sustain meaningful public interaction. They disagree about the rights of lay people to participate in science, and the potential benefits or risks of involving non-experts. Scientists prefer to respond to requests, rather than to initiate their own involvement. Scientists mainly target the youth and popular media, and often see public communication as a means to achieve goals such as recruiting students, demonstrating social impact and improving own and/or institution's image or gaining funding/political support. Scientists value the visibility that comes with public engagement, and often find public interactions satisfactory and enjoyable. Several factors, including their own communication skills, time constraints, institutional support and responses from their peers, influence the participation in public science communication of scientists.	Van der Auweraert, 2008
35. Knowledge exchanges between academics and the Business, Public and Third Sectors	Web survey with an achieved sample of 22 170 researchers	United Kingdom	The ivory tower is a myth. Academics in the United Kingdom are engaged with society in multi-faceted and nuanced ways. Mechanisms of interaction include people-based activities, problem-solving consultancies and community-oriented interactions. The most common form whereby academics externalise their research is via a consultancy, especially in fields such as engineering and materials science, with fewer than 10% of academics in arts and humanities involved. Public lectures and school projects are the preferred ways to interact with local communities.	Abreu, Grinevich, Hughes & Kitson, 2009
36. Public culture as professional science	Interviews with 30 scientists	United Kingdom	Public engagement emerges as a professional anomaly – increasingly acknowledged and valued, but simultaneously seen to be under-incentivised and under-rewarded, potentially detrimental to research, and professionally stigmatising. However, a major shift towards endorsement and recognition of public engagement within the culture of science is noted. Scientists reflect on the public, and public engagement, in a more sophisticated, layered and nuanced way than before and have become increasingly confident and enthusiastic about public engagement. The contrast between the positive view within the science community of the benefits of public engagement, and the difficulty of accommodating it in academic life, remains a key concern.	Burchell, Franklin & Holden, 2009

[98] English title: The researcher as communicator: A qualitative and exploratory investigation of the determinants of science communication behaviour.

Title	Method	Country	Key finding(s)	Citation
37. Socialization or Rewards? Predicting U.S Scientist-Media Interactions	A mail survey completed by 363 scientists	United States	Factors that determine scientists' engagement in outreach include the academic status of a researcher, their enjoyment and perceived impact of activities, their concern about the public/media reactions to research, their freedom and autonomy to decide whether and how to engage, as well as their past science communication training.	Dunwoody, Brossard & Dudo, 2009
38. (In)authentic sciences and, (im)partial publics: (re)constructing the science outreach and public engagement agenda	Focus groups and questionnaires to 36 scientists and others	United Kingdom	Most respondents have a much clearer understanding of science outreach than public engagement, and place a higher value on promoting science to the public in a deficit model style. Only a small number displayed evidence of dialogue and interaction. Personal enjoyment is a key reason for getting involved, while some are motivated by perceived professional responsibility.	Holliman & Jensen, 2009
39. Opening the Black Box: Scientists' Views on the Role of the Media in the Nanotechnology Debate	Online survey completed by 37 scientists, supplemented by 11 interviews	United Kingdom	While scientists acknowledge the significance of the media in shaping public perceptions of nanotechnologies, most are critical about media coverage. However, they often have a one-dimensional conception of science mediation that overlooks the influence of their own claims. Scientists need a better understanding of how the media work and the role of scientists in news production.	Petersen, Anderson, Allan & Wilkinson, 2009
40. Out of the Loop: Why Research Rarely Reaches Policy Makers and the Public and What Can be Done	A survey of 268 researchers	29 countries	Researchers prioritise communication with other scientists, and invest relatively little time and effort in communicating their findings to policy-makers or to local people, even less in working with the media. Popular communication is widely perceived as inconsequential in measuring scientific performance.	Shanley & Lopez, 2009
41. How and why scholars cite on Twitter	Interviews with 28 academics. Coding and analysis of 2 322 tweets.	United States	Scholars are increasingly using Twitter to cite articles, thereby adding to perceived scholarly impact. These citations are much faster than traditional citations (40% occurs within the first week after publication), and are also uniquely conversational.	Priem & Costello, 2010
42. The mobilization of scientists for public engagement	Re-analysis of earlier surveys	Data from different countries – United Kingdom, Europe, United States	About 75% of researchers have been involved in some form of public engagement, but only about 10% can be classified as "highly active". Researchers at senior levels in the organisation and academics (who focus on research only, instead of research and teaching) are more likely to engage with the public. A researcher's gender, age, support from colleagues and geographic region did not make a difference in terms of their involvement in public engagement.	Bauer & Jensen, 2011

Title	Method	Country	Key finding(s)	Citation
43. Academic staff and public communication: a survey of popular science publishing across 13 countries	Online survey with data drawn from 14 685 responses provided to a bigger project, targeting university researchers across 13 countries	Argentina, Australia, Brazil, Canada, Finland, Germany, Hong Kong, Italy, Malaysia, Mexico, Norway, UK & US	Popular science publishing is undertaken by a minority of academic staff and to a far lesser extent than scientific publishing. However, academics who do write popular articles, are of higher academics ranks and also produce more scientific articles. This positive relationship between scientific and popular publishing is consistent across all countries and academic fields. The extent of popular science publishing varies with field and country.	Bentley & Kyvik, 2011
44. Science and the media in South Africa: Reflecting a 'dirty mirror'	Online survey completed by 208 respondents (scientists and journalists)	South Africa	Scientists and journalists hold different views about the role of science in society and how best to communicate science to the public. There is a need for improved skills and expertise on both sides.	Claassen, 2011
45. Leading US nano-scientists' perceptions about media coverage and the public communication of scientific research findings	Mail survey completed by 363 scientists	United States	Nanoscientists feel a sense of responsibility for communicating research findings to the public, but they view media coverage of nanotechnology as less credible and accurate than media coverage of general science.	Corley, Kim & Scheufele, 2011
46. Gender Differences in Scientists' Public Outreach and Engagement Activities	Online survey completed by 810 scientists	Switzerland	Attitudes toward public outreach and engagement activities are the same among male and female scientists, but men are significantly more involved than women. Journalists also contact men more often than women. This gender difference remains, even after the effects of position, age, and faculty are removed.	Crettaz von Roten, 2011
47. Researcher Attitudes and Behaviour Towards the 'Openness' of Research Outputs in Agriculture and Related Fields	Online survey completed by 1 447 researchers	Several regions, including Latin America and Africa	In the complex set of factors that drive and shape the communication behaviour of scientists, institutional factors are very important and have much influence over the communication behaviour of individuals.	Edge, Martin, Rudgard & Thomas, 2011

Title	Method	Country	Key finding(s)	Citation
48. A statistical picture of popularization activities and their evolutions in France	Temporal content analysis of annual reports of 7 086 research grant-holders over six years	France	Researchers' participation in outreach is extremely uneven: the most active 5% of researchers do more than half of the activities. Over time, researchers are becoming more involved and online engagement is becoming more important. Age, gender, seniority and work role play a role, while activity in dissemination is also correlated with high academic indicators. Dissemination activities are not bad for scientists' careers, but not particularly good either – the effects are generally weak, but positive, and rarely significant.	Jensen 2011
49. Popularization by Argentine researchers: the activities and motivations of CONICET scientists	Online survey completed by 1 171 researchers	Argentina	Despite the differences in research practices between "central" and "peripheral" countries, patterns of science popularization in Argentina do not substantially differ from those found in France and the United Kingdom. Almost three quarters of scientists are engaged in some type of outreach, but for most it is an occasional activity, rather than part of their usual task. Senior researchers see media interviews as more prestigious, and younger researchers participate more in face-to-face events.	Kreimer, Levin & Jensen, 2011
50. Scientists' attitudes toward a dialogue with the public: a study using 'science cafés'	19 semi-structured interviews with early-career scientists who had participated in science cafés	Japan	Five key barriers make scientists apprehensive about participating in science cafés, namely (1) these events are too troublesome or time-consuming; (2) they experience pressure to be an appropriate science representative; (3) they regard these events as outside the scope of their work; (4) they do not perceive any benefit; and (5) they feel apprehensive about dialogue with the public. Apprehension about dialogue may be the clearest reflection of the scientists' underlying feelings about this form of communication and an indicator of more intrinsic barriers to engagement.	Mizumachi, Matsuda, Kano, Kawakami & Kato, 2011
51. Scientists' communication with the general public – an Australian Survey	Online survey completed by 1 521 scientists	Australia	Nearly 90% of Australian scientists agree that they have a responsibility to ensure timely public communication about their work. They engage in many ways, with face-to-face communication being more prevalent (82%) than communication via the Internet (45%) or media (44%). Public communication contributes to scientists' professional success through direct public participation or cooperation in the research. There are significant generational, disciplinary and gender differences in the type of activity and the barriers to communication, including time barriers and other hindrances in the workplace and institutional culture. Scientists want encouragement, support and reward for communication and the provision of opportunities to communicate.	Searle, 2011
52. Dissemination practices in the Spanish research system: scientists trapped in a golden cage	Online survey completed by 736 scientists	Spain	Spanish scientists want to communicate with the public, but perceive low interest from society and a lack of support within their professional environments. The type of activity is influenced by the age and gender of the scientists involved. Most scientists are motivated to take part in public outreach by moral considerations, rather than professional promotion	Torres-Albero, Fernández-Esquinas, Rey-Rocha &

Title	Method	Country	Key finding(s)	Citation
			or recognition. The barriers they face include time constraints and a lack of institutional support. They would value the consideration of research dissemination as a merit when it comes to evaluating their professional activity.	Martín-Sempere, 2011
53. The Influence of Presumed Media Influence on News About Science and Scientists	Online survey completed by 166 scientists, supplemented by bibliometric data analysis	Israel	There is no relationship between scientists' views about journalists' tendency towards sensationalism and scientists' motivation to seek out media coverage. The most important predictor of scientists' motivations and efforts is their belief that media appearances are part of an academic's duty.	Tsfati, Cohen & Gunter, 2011
54. Challenges for university engagement in the UK: Towards a public academe?	Interviews with 24 senior university managers	United Kingdom	UK scientists feel indecisive and anxious about public engagement, based on uncertainty about the legitimacy of public engagement as a core academic activity and the role of academics in communicating with public groups. There are many unresolved questions and concerns relating to the conceptualisation and manifestation of public engagement across different types of institutions and subject disciplines.	Watermeyer, 2011
55. Mind the gap and bridge the gap: research excellence and diffusion of academic knowledge in Sweden	Online survey completed by 9 788 faculty members, supplemented by 22 interviews	Sweden	In strong research environments, research excellence and knowledge production are clearly and virtuously linked to public dissemination activities. Researchers almost uniformly accept responsibility for public communication, but their involvement depends on their research productivity, with high-performing researchers significantly more involved.	Wigren-Kristoferson, Gabrielsson & Kitagawa, 2011
56. "Oh Yes, Robots! People Like Robots; the Robot People Should do Something": Perspectives and Prospects in Public Engagement With Robotics	Interviews with 24 individuals involved in public engagement events	United Kingdom	Robotics researchers are investing considerable time and effort in "engaging" publics, but some practical, conceptual, and individual influences continue to affect the level of engagement.	Wilkinson, Bultitude & Dawson, 2011
57. How and why the scientists communicate with society: The case of physics in Italy	Online survey completed by 1 559 physicists	Italy	Close to 80% of Italian physicists are involved in public communication, using a wide range of platforms, but favouring direct communication with their audiences. Science communication is an essentially no-profit (non-funded) activity and more than 80% of the involved scientists take part voluntarily. Lack of institutional recognition and investment,	Agnella, De Bortoli, Scamuzzi, Cerbara,

Title	Method	Country	Key finding(s)	Citation
			along with lack of peer interest and career benefits, are serious obstacles.	Valente & Avveduto, 2012
58. Mapping Variety in Scientists' Attitudes towards the Media and the Public: An Exploratory Study on Italian Researchers	Online survey completed by 295 researchers	Italy	There is significant variety in scientists’ attitudes towards the media and the public, which relate to different patterns of engagement in relevant activities, as well as to different models and conceptions of the science-media-public interaction.	Bucchi & Saracino, 2012
59. Behind closed doors. Scientists’ and science communicators’ Discourses on Science in Society. A study across European research institutions	Interviews with 48 scientists and communication professionals	United Kingdom, Germany, Portugal, Sweden, the Netherlands, Romania and Italy	Scientists are not isolated when they do research, nor when they interact with the public. Instead, they are influenced by the motivations and resources, including the PR policies and staff, within the organisations where they are employed. Researchers accept public communication as a moral duty and are willing to experiment with different engagement approaches, but mostly still cling to the deficit model of public science communication. When institutions fail to recognise science-in-society activities as an integral part of the research profession, this hampers public engagement.	Casini & Neresini, 2012
60. How academic biologists and physicists view science outreach	Interviews with 97 academic biologists and physicists	United States	Scientists’ outreach activities are stratified by gender and influenced by their field of research and perceptions of their own skills. Scientists experience significant barriers to outreach within their institutions, and from the general public. The view that outreach is ‘outside’ their responsibilities as university scientists, limits the time and ability of scientists to take part. Other disincentives include disapproval by mentors or departmental heads.	Ecklund, James & Lincoln, 2012
61. European Scientists' public communication attitudes: A cross-national quantitative and qualitative study of scientists' views and experiences and the institutional, local and national influences determining their public engagement activities	Interviews with 112 scientists from five European research centres	Germany, France, Italy, United Kingdom, Spain	Scientific communities share common values regarding public outreach with minimal differences between countries, but the level of activity vary distinctly, and is much higher in Germany, for example, than in Spain. Most scientists regard outreach as a low priority. The level of activity is clearly associated with levels both of institutional support (such as the presence of public relations and press officers) and the national and local public policies favourable to the activity.	Escutia, 2012
62. Variations of scientist-journalist interactions across academic fields: Results of a	Online survey completed by 1 600	Germany	There are clear-cut differences in the science-media interface between academic fields. Compared to the hard sciences, humanities and social sciences are characterised by stronger interdependency with journalism, and less distance between scientific and public	Peters, Spangenberg

Title	Method	Country	Key finding(s)	Citation
survey of 1600 German researchers from the humanities, social sciences and hard sciences	researchers		communication. There is also a lower demarcation of scientific knowledge from everyday knowledge in the social sciences, compared to hard sciences, and a lower level of professionalisation when it comes to interactions with journalists.	& Lo, 2012
63. On being a (modern) scientist: risks of public engagement in the UK interspecies embryo debate	Ten interviews with senior researchers	United Kingdom	Scientists are faced with difficult choices regarding the potential gains and risks of media publicity. When dealing with controversial issues, some scientists think that public communication damage their professional standing and careers. There are also tensions between promoting science versus promotion of the scientist; engaging the public versus publishing peer-reviewed articles and spending time on getting research funding.	Porter, Williams, Wainwright & Cribb, 2012
64. The ambivalence of visible scientists	In-depth interviews with 55 researchers	France, Germany, United Kingdom, United States	Transformations in the normative structure of science are indicative of the changes between science and other spheres of society, such as politics and mass media. Scientists willing to engage in raising the public visibility of their university may still find that it could tarnish their scientific reputation. Consequently, many scientists remain ambivalent about media visibility.	Rödder, 2012
65. Measuring the Impact Values of Public Engagement in Medical Contexts	Qualitative survey of 84 researchers	United Kingdom	Medical researchers attribute different impact values to public science engagement. Engagement impacts on researchers and the research process, but also the public image and reputation of research and researchers. Researchers show limited support for the idea of upstream engagement. Instead, public engagement is more frequently encouraged in the context of justifying, promoting and defending medical research.	Watermeyer, 2012
66. Medialized science? Neuroscientists' reflections on their role as journalistic sources	Interviews with 30 scientists	United States, Germany	Most neuroscientists perceive benefits associated with media coverage and are willing to cooperate with journalists, but are concerned about journalistic quality and risks stemming from public visibility. They also fear the negative consequences of being distracted from research as a result of the time demands of media interactions.	Allgaier, Dunwoody, Brossard, Lo & Peters, 2013
67. How scientists view the public, the media and the political process	Re-analysis of two large-scale surveys	United States, United Kingdom	Scientists believe the public is uninformed about science and therefore prone to errors in judgment and policy preferences. Scientists are critical of media coverage, but generally believe media work is important and tend to rate their own media interactions more favourably. They believe they have a role to play in public debates.	Besley & Nisbet, 2013
68. Predicting scientists' participation in public life	Secondary data analysis of two earlier studies	United States, United Kingdom	The participation of scientists in public life differs depending on their career stage, discipline, view of the public and their own attitudes. Mid-career scientists are more likely to be involved, while chemists are participating less than others. Scientists who believe that a lack of public knowledge about science could be harmful, and who feel that they are	Besley, Oh & Nisbet, 2013

Title	Method	Country	Key finding(s)	Citation
			able and obliged to communicate with the public, see outreach as more important than others.	
69. Research staff and public engagement: A UK study	Online survey completed by 273 researchers, supplemented by focus groups	United Kingdom	There is a central tension in the drive towards public engagement in the UK academic environment. It is advocated and demanded on the one hand, but remains difficult to practice, particularly for contract staff. Researchers see public science engagement as necessary and rewarding, but experience significant challenges which constrain their involvement. In addition to the need for logistical support and training, researchers are concerned that it may affect their job security and autonomy.	Davies, 2013
70. Toward a model of scientists' public communication activity: The case of biomedical researchers	Mail survey completed by 363 scientists	United States	Key factors that contribute to scientists' public communication activity include status, autonomy, own media habits, intrinsic rewards, communication training, perceived behavioural controls, normative beliefs, and perceived level of medialisation; no link found between gender and his or her level of public communication. Scientific institutions that are serious about improving public engagement should identify and support scientists who find, or might find, public communication enjoyable and rewarding.	Dudo, 2013
71. A Field of Expertise, the Organization, or Science Itself? Scientists' Perception of Representing Research in Public Communication	Interviews with 20 leading scientists	Denmark	Three different modes of representation are identified: Expert, Research Manager, and Guardian of Science. Each of these modes of representation implies particular notions of quality, audience, motivation, and learning in science communication.	Horst, 2013
72. Is There a Medialization of Climate Science? Results From a Survey of German Climate Scientists	Online survey completed by 1 130 scientists	Germany	Medialisation is present in climate sciences, but there are differences between subgroups in the field. While media interactions are more common for high-ranking scientists, scientists with less experience are more likely to adapt to media criteria.	Ivanova, Schäfer, Schlichting & Schmidt, 2013
73. Narratives of Science Outreach in Elite Contexts of Academic Science	Interviews with 133 physicists and biologists	United States	The cultural properties of disciplines, including the status of women, shape the meaning and experience of science outreach. A comparison of physicists and biologists reveal some of the barriers and motivations for public engagement that are tied to discipline and gender. While physicists view outreach as outside of their scientific roles and a possible threat to their reputations, biologists assign greater value to outreach, but their perceptions of the public inhibit commitment. Women are more likely than men to participate in outreach, a commitment that often results in peer-based informal sanctions.	Johnson, Ecklund & Lincoln, 2014

Title	Method	Country	Key finding(s)	Citation
74. Studies on Scientists' Engagement in Public Outreach in China: Motivations, Impediments and Countermeasures	Interviews with 21 senior researchers	China	Most scientists view outreach as a form of volunteer work that is secondary to their other responsibilities. The strongest motivating factor is the desire to contribute to society, while limited time is a significant barrier. Scientists at all career stages participate in public outreach for similar reasons, but subtle shifts occur in their motivations as scientists become more senior and their priorities change. The most important limiting factor is the fact that scientists' efforts in public outreach are significantly undervalued in the existing scientific research and education evaluation system in China.	Qi, Xuan & Fujun, 2013
75. Gap between science and media revisited: Scientists as public communicators	Cross-national data analysis of earlier postal and online surveys	United States, Japan, Germany, United Kingdom, France	Science-media relationships and collaborations seem to be improving. Most scientists consider visibility in the media important and responding to journalists a professional duty—an attitude that is reinforced by universities and other research organisations. Scientific communities continue to regulate media contacts with their members by certain norms that compete with the motivating and regulating influences of PR departments. Most scientists assume a two-arena model with a gap between the arenas of internal scientific and public communication. They want to meet the public in the public arena, not in the arena of internal scientific communication.	Peters, 2013
76. Commentators on daily news or communicators of scholarly achievements? The role of researchers in Danish news media	Interviews with 362 journalists and 342 scientists, plus content analysis of 640 articles	Denmark	Researchers who contribute to news media are mainly males with 5 to 15 years of experience. University-based scientists from the social sciences and humanities contribute on a regular basis, mostly as public experts commenting on daily events. They consider contributing to news media both a duty and a career-enhancing activity. Both journalists and scientists perceive the cooperation positively, although researchers tend to be more reserved than the journalists.	Wien, 2013
77. Public engagement and science communication survey	Online survey; 267 researchers and students funded by BBSRC	United Kingdom	Comparing the public engagement attitudes and activities of principal investigators and PhD students reveal notable differences, demonstrating a clear distinction between the ways senior academic staff communicate their research relative to more junior researchers. For example, PhDs find social media easier, while principal investigators are more comfortable working with journalists.	BBSRC, 2014
78. An analysis of nanoscientists as public communicators	Mixed-mode, multi-wave survey of 216 scientists and engineers	United States	Nanoscientists frequently participate in public communication. They see it as a necessary and gratifying activity and mostly view their communication efforts as having positive impacts on their careers and professional development.	Dudo, Kahlor, AbiGhannam, Lazard & Liang, 2014

Title	Method	Country	Key finding(s)	Citation
79. Building buzz: (Scientists) Communicating Science in New Media Environments	Interviews with 21 senior researchers	United States	Public communication can contribute to a scholar's scientific impact and being mentioned on Twitter amplifies the effect of interactions with journalists and other non-scientists on the scientific impact of the scholar.	Liang, Su, Yeo, Scheufele, Brossard, Xenos, Nealey & Corley, 2014
80. Organizational influence on scientists' efforts to go public: an empirical investigation	Online survey completed by 942 researchers	Germany	A large proportion of scientists from all disciplines participate regularly in the dissemination of research findings. Their media efforts are influenced by how they adopt the desire of their university to be visible in the media, as well as by the PR activities of the university.	Marcinkowski, Kohring, Fürst & Friedrichsmeier, 2014
81. Comparison Study on China-UK Scientists' Engagement in Public Outreach Activities	Scientist interviews, compared with literature study	United Kingdom, China	A comparison of a UK and a Chinese university setting shows that institutional commitment to and support structures for public engagement can benefit public engagement efforts significantly. Scientists at University College London (UK) are also motivated by a visible annual rewards programme for public engagement and inclusion of engagement elements in academic promotions criteria.	Ren, Liu, Wang & Yin, 2014
82. What do scientists think about the public and does it matter to their online engagement?	Online survey completed by 431 scientists (AAAS members[99])	United States	Scientists are largely positive about public engagement and their activities correlate with social norms, efficacy and a desire to contribute to public debate. Their current views are largely not correlated with earlier experiences of online engagements or willingness to engage in the future.	Besley, 2015
83. Scientists' Views About Communication Training	Online survey completed by 425 university scientists who are also AAAS members	United States	In terms of training, scientists rate message comprehension and credibility most favourably and give their lowest rating to training related to framing. Believing that public engagement can make a difference and belief in the ethicality of specific goals were the best predictors of whether scientists saw value in goal-oriented training.	Besley, Dudo & Storksdieck, 2015
84. Safe and Sound? Scientists' Understandings of Public Engagement in Emerging Biotechnologies	Interviews with 12 scientists	Germany	Scientists perceive the public as holding a primarily risk-focused view of science. On the one hand, different forms of science communication are thereby either seen as a chance to improve the public acceptance of science in general and one field of research in particular.	Braun, Starkbaum & Dabrock, 2015

[99] Members of the AAAS (American Association for the Advancement of Science) are expected to be mainly based in the USA, but some members reside in other countries.

Title	Method	Country	Key finding(s)	Citation
			On the other hand, the exchange with the public is seen as a duty because the whole of society is affected by scientific innovation.	
85. Understanding Academics' Popular Science Publishing: Institution Culture and Management Style Effects	Data analysis based on a large-scale survey of academics conducted between 2007 and 2010	Austria, Croatia, Finland, Germany, Italy, United Kingdom, Ireland, the Netherlands, Norway, Poland, Portugal, Switzerland	The profiles of scientists involved in public outreach are highly varied, and the relationships between disciplines and public outreach vary from country to country. Organisational contexts determine the climate for public outreach. Across the 12 countries studied, about half the popular articles were written by just 5% of the scientists.	Crettaz Von Roten & Goastellec, 2015
86. How Astronomers view education and public outreach: An exploratory study	Survey completed by 155 astronomers	Global	Many astronomers think that a larger percentage of their research funding – on average 5 to 10% – should be invested into outreach activities. They are mostly positive about outreach and senior astronomers encourage their students to participate.	Dang & Russo, 2015
87. The science-media interaction in biomedical research in the Netherlands. Opinions of scientists and journalists on the science-media relationship	Interviews with 21 scientists	The Netherlands	Different behavioural, normative and control beliefs underlie scientists' and journalists' participation in science-media interactions. Both groups are positive about science-media interactions, but scientists perceive various disadvantages in this relationship while journalists perceive mainly practical barriers.	Dijkstra, Roefs & Drossaert, 2015
88. Organisational Culture and Its Role in Developing a Sustainable Science Communication Platform	Interview with 12 participants, including eight scientists	New Zealand	Public engagement does not hamper research or research funding. The research reveals that scientists perceive an obligation to communicate with external audiences, that science needs to be communicated on the listener's terms, and that scientists need public communication training.	France, Cridge & Fogg-Rogers, 2015

Title	Method	Country	Key finding(s)	Citation
89. Mapping Public Engagement with Research in a UK University	Data extracted from the responses of 171 researchers in earlier surveys	United Kingdom	Scientists widely acknowledge the benefits of public engagement and have mostly positive attitudes about being involved. For many UK academics public engagement is closely entangled with demands for social and economic impact. Researchers offer a relatively limited view of public engagement with research: their definitions are mostly focused on the dissemination, communication or presentation of research.	Grand, Davies, Holliman & Adams, 2015
90. Taiwanese life scientists less "medialized" than their Western colleagues	Online survey completed by 596 scientists	Taiwan, Germany	Fewer Taiwanese than German researchers have frequent contact with the media and they rate their experiences with journalists less positively. Furthermore, they are less prepared to adapt to journalistic expectations and expect journalists to consider scientific criteria in their reporting. However, Taiwanese scientists are more willing than German scientists to accept journalistic simplification at the expense of accuracy.	Lo & Peters, 2015
91. Assessing the Impact of Education and Outreach Activities on Research Scientists	Interviews with 12 scientists	United States	While most researchers value education and outreach activities, many encounter obstacles to such efforts. These obstacles include a lack of support or resources at their home institution, the effort required to balance their research careers and outreach activities, and the need to find ways to connect with lay audiences. Younger, non-tenured researchers are more eager to be involved compared to their older, tenured colleagues.	McCann, Cramer & Taylor, 2015
92. A Socioenvironmental Shale Gas Controversy: Scientists' Public Communications, Social Responsibility and Collective Versus Individual Positions	Discourse analysis, interview with 13 scientists and two focus groups	France	Scientists become engaged in communication about their work because of their collective feeling of social responsibility in response to perceived public demand, their collective ad hoc expertise and the need to produce neutral (and therefore credible) statements on the topic.	Molinatti & Simonneau, 2015
93. Expertise in an age of polarization: Evaluating scientists' political awareness and communication behaviors	Data extracted from a large survey of AAAS members, completed by 2 533 scientists	United States	Ideology, partisanship and opinion-intensity are not predictive of media and communication behaviours. Instead, the strongest predictor is the belief that media coverage is important for an individual's career advancement.	Nisbet & Markowitz, 2015
94. How scientists engage the public	Online survey completed by 3 748 AAAS-	United States	Most scientists believe it is important to participate in public debate. Almost half use social media and nearly a quarter use blogs to discuss their work and learn about the research of others. Scientists who are most likely to be involved in public activities show distinct patterns by the level of public debate and public interest they perceive in their specialty,	Pew Research Center, 2015

Title	Method	Country	Key finding(s)	Citation
	member scientists		and by discipline. More engaged scientists typically work on topics where they feel there is public interest.	
95. Factors affecting public engagement by researchers: A study on behalf of a Consortium of UK public research funders	Online survey completed by 2 454 researchers and 269 enablers	United Kingdom	The vast majority of researchers have done at least one public engagement activity in the previous year. Participation in public engagement is higher among researchers in the arts, humanities and social sciences, than in natural sciences, technology, engineering and mathematics. About two thirds of researchers report that their institutions are providing more support for outreach than before. Significant obstacles include time pressures, difficulty accessing relevant opportunities and insufficient funding.	TNS BMRB, 2015
96. Lost in the 'third space': the impact of public engagement in higher education on academic identity, research practice and career progression	Interviews with 40 researchers	United Kingdom	Public engagement may have a deleterious effect on academic identity; research practice and career progression. Because of its time-demanding and labour-intensive nature, public engagement is seen as fundamentally incompatible with the time and management frameworks at universities. Managerial support is dictated by chance and the individual liking, sympathy and generosity of line-managers for individual researchers. Support is often granted conditionally on the proviso that it must not detract from research time and institutional business.	Watermeyer, 2015a
97. Public intellectuals vs. New public management: The defeat of public engagement in higher education	Interviews with 40 researchers	United Kingdom	Organisational structures and institutional priorities at universities, especially time management systems, are significant barriers deterring academics from participation in public engagement. Lack of evaluation of public engagement continues to exclude these activities from institutional expectations in terms of what constitutes excellence and/or proper use of academic time. Despite this, public engagement survives and is the academic lifeblood and means of self-justification for some researchers.	Watermeyer, 2015b
98. How are UK Academics Engaging the Public with their Research? A Cross-Disciplinary Perspective	Online survey completed by 260 researchers and interviews with 24 researchers	United Kingdom	There is no association between an academics' discipline and whether she/he participates in public engagement. An association does exist between certain disciplinary groups and particular audiences, whereby some audiences are more relevant to some disciplinary groups than others. Academics with more research experience are more likely to take part in public engagement than those who are less experienced. Some academics use creative ways of engaging the public with their research, while some use PR firms and/or social media. Academics value autonomy in deciding which audiences to engage and therefore most of them view mandating public engagement as part of an appraisal system unfavourably.	Chikoore, Probets & Creaser, 2016

Title	Method	Country	Key finding(s)	Citation
99. Scientists' Prioritization of Communication Objectives for Public Engagement	Online survey completed by 390 AAAS members	United States	Scientists prioritise communication designed to educate the public and defend science from misinformation. They attach the lowest priority to communication that seeks to build trust and establish resonance with the public.	Dudo & Besley, 2016
100. Mobilisation for public engagement: Benchmarking the practices of research institutes	Online survey completed by 234 research institutes	Portugal	Most researchers participate in engagement, but the intensity of their involvement differs across scientific areas. Researchers in social sciences and humanities are more active across more channels, while natural science researchers are more likely to mobilise high performers for public engagement. Lack of resources, as well as lack of enthusiasm, skills and time are the main reasons for not undertaking public communication.	Entradas & Bauer, 2016
101. "We muddle our way through": shared and distributed expertise in digital engagement with research	Interviews with 15 researchers	United Kingdom	Despite little evidence of systematic changes in how researchers use digital tools in public engagement, the increasing expectations around digital engagement cause researchers to re-assess their research identities.	Grand, Holliman, Collins & Adams, 2016
102. Mapping Neuroscientists' Perception of the Nature and Effects of Public Visibility	In-depth interviews with 24 scientists	United States	Scientists are factoring new communication channels into their public visibility strategies. One legacy medium, The *New York Times* remains the holy grail of medialisation. They associate public visibility gained from the NYT with an enhanced reputation in the science community, potentially leading them to consider the criteria of the newspaper for news in assessing their own research.	Koh, Dunwoody, Brossard & Allgaier, 2016
103. Blogging by scientists: a rare and peripheral activity	Online survey completed by 815 scientists	Germany, United States, Taiwan	While blogging scientists hardly blog specifically for the general public, they consider members of the public an important audience besides their peers and students. Very few scientists in Taiwan, Germany and the United States (3–5%) are blogging about their science. For those who do blog, it remains a marginal activity.	Lo & Peters, 2016
104. Online communication beyond the scientific community: Scientists' use of new media in Germany, Taiwan and the United States to address the public	Online survey completed by 815 scientists	United States, Taiwan, Germany	Very few scientists read online blogs and even fewer write blog posts themselves. Bloggers and non-bloggers share basic beliefs about public communication. Based on audience responses, there are no indications of strong medialisation effects by blogging. There are differences in the views of Taiwanese scientists regarding public science engagement compared to their western counterparts in Germany and the US.	Lo, 2016
105. Scientists in the public sphere: Interactions of scientists and journalists in Brazil	Online survey of 956 scientists	Brazil	Scientists have clear and high expectations about how journalists should act when reporting on science, but feel that their expectations are often not met. Most rate their	Massarani & Peters, 2016

Title	Method	Country	Key finding(s)	Citation
			interaction with the media positively and see the media as having positive impacts on colleagues.	
106. Science and social engagement. Public communication of science as a cultural practice of the scientific community in Mexico	Online survey completed by 3 950 researchers	Mexico	Mexican scientists are willing to communicate with the public, and are investing effort and time into these activities. They consider communication training as an important part of graduate science education. Their view of public communication is still mostly a deficit (teaching) model, with a particular aim to articulate academic work to society, and especially to poor and marginalised sectors of society.	Namihira-Geurrero, 2016
107. Public science communication in Africa: views and practices of academics at the National University of Science and Technology in Zimbabwe	Hard copy survey completed and returned by 198 academics	Zimbabwe	This case study of Zimbabwean academics reveal that public science communication suffers from a low status in African countries, with academics paying little attention to audiences outside the scientific arena. The majority of academics believe that African publics are not science literate or interested in science. An unstable funding environment, lack of support structures and fear of political censorship further limit researchers' interest in engaging with the media or public audiences.	Ndlovu, Joubert & Boshoff, 2016

Appendix 2: Text of email sent to science-media panel members

Dear … *[insert title, name, surname]*

PLEASE HELP ME TO IDENTIFY PUBLICLY VISIBLE SCIENTISTS IN SOUTH AFRICA

I'm currently busy with a PhD research project looking into the factors that affect if, why and how scientists communicate with public audiences. I am planning to interview at least 20 high-profile scientists early in 2017. That is why I need your help in identifying publicly visible scientists in South Africa.

I would be very grateful if you could write down names of about five to ten scientists – currently living and working in South Africa – whom you consider to be publicly visible. In other words, I'm looking for names of active scientists that are making an effort to communicate with the public about their work and who may, consequently, be visible via traditional and social media platforms.

Please be liberal in your definition of a scientist. You are welcome to include natural, agricultural and environmental scientists, but also doctors, engineers and social scientists – anyone who might be considered a scientist or researcher in the public image.

Please send these names to me by replying to this email message. If you are able to add their affiliations, that would help me tremendously. I hope to hear from you by 15 December 2016.

Unless you have any objections to being mentioned, I will include your name in a list of the science communication and media experts that I contacted to assist me in identifying the publicly visible scientists in South Africa. I will not associate your name with any specific scientists identified.

Thank you very much for helping me with this project. I appreciate it deeply.

Yours sincerely,

Marina Joubert
Researcher: Science communication
CREST (Centre for Research on Evaluation, Science and Technology)
Stellenbosch University
South Africa

Appendix 3: Science-media panel respondents (n = 46)

Last and first name	Affiliation	Industry sector[100]
Alfreds, Duncan	Media24	Online (general news website)
Bega, Sheree	Saturday Star	Print media (newspaper)
Blaine, Sue	Financial Mail	Print media (magazine)
Boaduo, Nana	National Research Foundation	Research management
Boje, Val	Pretoria News	Print media (newspaper)
Brits, Elsabe	*Die Burger*	Print media (newspaper)
Carnie, Tony	The Mercury	Print media (newspaper)
Child, Katharine	The Times	Print media (newspaper)
Cowling, Lesley (Prof)	University of the Witwatersrand	Research
De Klerk, Marize	Video News 247	Online (video news)
Du Plessis, Izak	SABC	Broadcast (radio)
Dugmore, Harry (Prof)	Rhodes University	Research
Duvenage, Engela	Freelance	Science communicator
Eliseev, Alex	EWN	Broadcast (radio)
Genis, Amelia	*Landbouweekblad*	Print media (magazine)
Groenewald, Yolandi	City Press	Print media (newspaper)
Ilbury, Daryl	Freelance	Science communicator
Joseph, Natasha	The Conversation Africa	Online (research news and opinion)
Kahn, Tamar	Business Day	Print media (newspaper)
Labuschagne, Lia	Freelance	Science communicator
Landman, Ruda	Freelance	Freelance (television)
Lang, Steven	Freelance	Freelance (print media)
Lelliot, Tony	University of the Witwatersrand	Research
Limson, Janice (Prof)	Rhodes University	Research
Lombard, Stephan	Cape Talk Radio	Broadcast (radio)
Makoni, Munya	Freelance	Online and print media
Malan, Mia	Mail & Guardian	Print media (newspaper)
Minnaar, Izak	SABC	Online (news)
Mumm, Anina	ScienceLink	Science communicator
Nkone, Thabiso	National Research Foundation	Research management
Nordling, Linda	Freelance	Print media
Riley, Joanne	National Research Foundation	Research management
Robinson, Freek	*KykNet*	Broadcast (television)
Roos, Ina	Freelance	Print media
Sboros, Marika	Freelance	Print media
Schütz, Elna	The Wits Radio Academy	Broadcast (radio)
Smallhorne, Mandi	Freelance	Print and online media
Smit, Lynne	Hippo Communications	Science communicator
Stone, Ginny	SAASTEC	Science centres network
Tempelhoff, Elise	*Beeld*	Print media (newspaper)
Thom, Anso	Health-e/Section27	Online (health news)
Venter, Irma	Engineering News	Print media (magazine)
Watts, Derek	Carte Blanche	Broadcast (television)
Wiener, Mandy	Freelance	Broadcast (radio)
Wild, Sarah	Freelance	Print and online media
Yeld, John	Freelance	Print media

[100] Note: All the print and broadcast media outlets listed here also have an online presence and digital platforms.

Appendix 4: Text of email sent to interview participants

Dear Professor/Dr *[insert first name/surname]*

REQUEST FOR AN INTERVIEW

You have been identified as one of the most visible scientists in South Africa by a panel of more than 40 science-media experts. This was the first phase in my PhD research project designed to understand the factors that influence the public communication behaviour of scientists.

I would therefore be most grateful if you would agree to be interviewed by me, in order to gain your views and insights about the public communication of your research. The interview will last about one hour and will be audio-recorded for transcription purposes. I will contact your office to set up a suitable date and time for the interview. I'm happy to come to your office, home or other venue of your choice.

Because of the nature of the topic (gathering views from publicly visible scientists), I hope that you will be amenable to being identified as a study participant, as well as to be quoted in my dissertation and associated academic and popular research outputs. I will make the transcript of the interview available to you (before processing the data), so that you will be able to make changes until you feel comfortable with the text. Also, I will make any text in my dissertation where you are quoted available to you for your review and approval prior to finalising the study.

This study has been approved by the Humanities Research Ethics Committee (HREC) at Stellenbosch University and will be conducted according to accepted and applicable national and international ethical guidelines and principles. Your participation is entirely voluntary and you are free to decline to participate now, or at a later stage of this study. If you decide to withdraw, this will not affect you negatively in any way whatsoever. You may also choose not to answer any specific question(s).

If you have any questions or concerns about the research, please feel free to contact me at marinajoubert@sun.ac.za or my study leader Prof Peter Weingart at weingart@sun.ac.za.

Yours sincerely,

Marina Joubert
Researcher: Science communication
CREST (Centre for Research on Evaluation, Science and Technology)
Stellenbosch University
South Africa

Appendix 5: The 18 most publicly visible scientists in South Africa[101]

Surname, name (title)	Broad research field	Institution	Mentions
Berger, Lee (Prof)	Natural sciences	University of the Witwatersrand	27
Noakes, Tim (Prof)	Health sciences	University of Cape Town	14
Gray, Glenda (Prof)	Health sciences	Medical Research Council	12
Scholes, Bob (Prof)	Environmental sciences	University of the Witwatersrand	10
Salim Abdool-Karim (Prof)	Health sciences	University of KwaZulu-Natal and Centre for the Aids Programme of Research in South Africa (CAPRISA)	10
Chinsamy-Turan, Anusuya (Prof)	Natural sciences	University of Cape Town	8
Soodyall, Himla (Prof)	Natural sciences	University of the Witwatersrand	8
Fanaroff, Bernie (Dr)	Physical sciences	South African Square Kilometre Array Project[102]	7
Turton, Anthony (Prof)	Environmental sciences	University of the Free State	6
Bekker, Linda-Gail (Prof)	Health sciences	University of Cape Town	5
Nyokong, Tebello (Prof)	Physical sciences	Rhodes University	5
Pepler, Dave (Mr)	Environmental sciences	Academy for Environmental Leadership	4
Mayosi, Bongani (Prof)	Health sciences	University of Cape Town	4
Rubidge, Bruce (Prof)	Natural sciences	University of the Witwatersrand	4
Chibale, Kelly (Prof)	Physical sciences	University of Cape Town	4
Thackeray, Francis (Prof)	Natural sciences	University of the Witwatersrand	4
Farrant, Jill (Prof)	Natural sciences	University of Cape Town	4
Makunga, Nox (Prof)	Natural sciences	Stellenbosch University	4

[101] These 18 scientists were mentioned by 4 of more members of the science-media panel
[102] The South African Square Kilometre Array Project is an initiative of the country's Department of Science and Technology, managed by the South African National Research Foundation (NRF).

Appendix 6: Scientists participating in the current study (n = 30)

Surname, name (title)	Broad field	Research interests	Institu-tion	Population group	Gender	Year of birth
*Abdool-Karim, Salim (Prof)	Health sciences	Epidemiology and infectious diseases	UKZN	Black (Indian)	Male	1960
Albertyn, Cathi (Prof)	Social sciences	Gender equality and law	WITS	White	Female	1958
*Bekker, Linda-Gail (Prof)	Health sciences	HIV and tuberculosis	UCT	White	Female	1962
*Berger, Lee (Prof)	Natural sciences	Palaeoanthropology	WITS	White	Male	1965
Byrne, Marcus (Prof)	Natural sciences	Insects for biocontrol	WITS	White	Male	1959
*Chibale, Kelly (Prof)	Physical sciences	Drug discovery and medicinal chemistry	UCT	Black (African)	Male	1964
*Chinsamy-Turan, Anusuya (Prof)	Natural sciences	Dinosaur palaeobiology	UCT	Black (Indian)	Female	1962
Cowan, Don (Prof)	Natural sciences	Micro-organisms in natural environments	UP	White	Male	1954
*Farrant, Jill (Prof)	Natural sciences	Drought tolerance in plants	UCT	White	Female	1961
Forbes, Andrew (Prof)	Physical sciences	Photonics	WITS	White	Male	1969
Gobodo-Madikizela, Pumla (Prof)	Social sciences	Trauma and reconciliation	SU	Black (African)	Female	1955
Gouws, Amanda (Prof)	Social sciences	Political sciences	SU	White	Female	1969
*Gray, Glenda (Prof)	Health sciences	Perinatal HIV/Aids	MRC	White	Female	1962
Hendriks, Sheryl (Prof)	Natural sciences	Food security	UP	White	Female	1967
Kana, Bavesh (Prof)	Health sciences	Tuberculosis	WITS	Black (Indian)	Male	1975
*Makunga, Nox (Prof)	Natural sciences	Medicinal plants	SU	Black (African)	Female	1971
Maluleke, Tinyiko (Prof)	Social sciences	Religion and politics	UP	Black (African)	Male	1961
*Noakes, Tim (Prof)	Health sciences	Sports science and nutrition	UCT	White	Male	1949
*Nyokong, Tebello (Prof)	Physical sciences	Medicinal chemistry and nanotechnology	RU	Black (African)	Female	1951
Oni, Tolullah (Prof)	Health sciences	Public health	UCT	Black (African)	Female	1980
*Pepler, Dave (Mr)	Natural sciences	Ecology and conservation	AEL	White	Male	1950
Richter, Linda (Prof)	Social sciences	Human development	WITS	White	Female	1950
*Rubidge, Bruce (Prof)	Natural sciences	Karoo palaeontology	WITS	White	Male	1956
*Scholes, Bob (Prof)	Natural sciences	Ecology	WITS	White	Male	1957
Scholes, Mary (Prof)	Natural sciences	Systems analysis	WITS	White	Female	1957
*Soodyall, Himla (Prof)	Natural sciences	Population genetics and molecular anthropology	WITS	Black (Indian)	Female	1963
*Thackeray, Francis (Prof)	Natural sciences	Palaeontology	WITS	White	Male	1952
*Turton, Anthony (Prof)	Natural sciences	Water	UFS	White	Male	1954
Venkatakrishnan, Hamsa (Prof)	Social sciences	Education	WITS	Black (Indian)	Female	1967
Walker, Cherryl (Prof)	Social sciences	Land reform and rural development	SU	White	Female	1951

*These 16 scientists were part of the group of 18 most visible scientists identified in the current study, as listed in Appendix 5.

Appendix 7: Invitation to participate and declaration of consent

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REQUEST TO PARTICIPATE IN RESEARCH

TITLE OF THE RESEARCH PROJECT: Understanding the factors that influence the public communication behaviour of scientists

REFERENCE NUMBER FOR ETHICS CLEARANCE: SU-HSD-004069

RESEARCHER: Marina (CM) Joubert

ADDRESS: Centre for Research on Evaluation, Science and Technology (SA Research Chair in Science Communication research group), Stellenbosch University, South Africa

CONTACT NUMBERS: 021 808-9609 / 0834094254
Email: marinajoubert@sun.ac.za

Dear colleague

My name is Marina Joubert and I would like to invite you to participate in a science communication research project entitled **“Understanding the factors that influence the public communication behaviour of scientists”** by agreeing to be interviewed by me**.**

Your participation is **entirely voluntary** and you are free to decline to participate now, or at a later stage of this study. If you decide to withdraw, this will not affect you negatively in any way whatsoever. You may also choose not to answer any specific question(s).

This study has been approved by the **Humanities Research Ethics Committee (HREC) at Stellenbosch University** and will be conducted according to accepted and applicable national and international ethical guidelines and principles.

Based on your past involvement in public communication of science, your views and insights will be invaluable to this study. If you agree, I will contact you to schedule a time and venue for a 1.5-hour interview which will be done in person, or via Skype as an alternative. All interviews will be audio-recorded for transcription purposes.

Because of the nature of the topic (gathering views from publicly visible scientists), I hope that you will be amenable to being identified as a study participant, as well as to be quoted in my dissertation and associated academic and popular research outputs. I will make the transcript of the interview available to you (before processing the data), so that you will be able to make changes until you feel comfortable with the text. Also, I will make any text in my dissertation where you are quoted available to you for your review and approval prior to finalising the study.

If you have any questions or concerns about the research, please feel free to contact me at marinajoubert@sun.ac.za or my study leader Prof Peter Weingart at weingart@sun.ac.za.

RIGHTS OF RESEARCH PARTICPANTS: You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research subject, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development. You have right to receive a copy of the 'Information and Consent' form.

If you are willing to participate in this study please sign the "Declaration of Consent" (on the next page) and hand it to me (when we meet) or email a signed, scanned copy to marinajoubert@sun.ac.za).

Yours sincerely

Marina Joubert
Researcher: Science communication
CREST (Centre for Research on Evaluation, Science and Technology)
Stellenbosch University
South Africa

DECLARATION BY PARTICIPANT

By signing below, I ……………………………………………………………………. agree to take part in a research study entitled "Understanding the factors that influence the public communication behaviour of scientists", conducted by Marina Joubert.

I declare that:

- I understand what the research project is about.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.
- All issues related to privacy and the confidentiality and use of the information I provide have been explained to my satisfaction.

Signed at (*place*)

____

___________________________________	_______________________________________
Signature of participant	**Date**

DECLARATION BY INVESTIGATOR

I declare that I explained the information given in this document to …………………………………………

I encouraged the participant to ask me any questions pertaining to the research. This conversation was conducted in English and no translation was required.

_____________________________________	_______________________________________
Signature of investigator	**Date**

Interesting snippets about some scientists interviewed for this study

Kelly Chibale is one of the Quartz Africa innovators for 2017.

A TED talk by **Marcus Byrne**, called 'Dance of the Dung Beetle' has been viewed more than 1 million people (1 004 699 views on 2 October 2017). In 2013, he was part of a research team that won the Ig Nobel Prize for discovering how dung beetles navigate by using the Milky Way for orientation.

Lee Berger was named one of the most influential people of 2016 by *Time* magazine, and was also named 2016 'Explorer of the Year' by the National Geographic Society.

In recognition for his extensive contribution to palaeontology in South Africa, **Francis Thackeray** received the Order of Merit (Chevalier) from the Republic of France in 1998.

Since joining Twitter in 2012, **Tim Noakes** has tweeted 37 559 times and gained 94 045 followers (as at 2 October 2017).

Jill Farrant was the L'Oréal-UNESCO Awards Laureate for Africa. Her TED talk 'How to make crops survive without water' has been viewed more than 1.3 million times (1 333 840 views by 2 October 2017).

In 2014, **Bob Scholes** became one of a small group of South African scientists elected as a foreign associate of the US National Academy of Sciences.

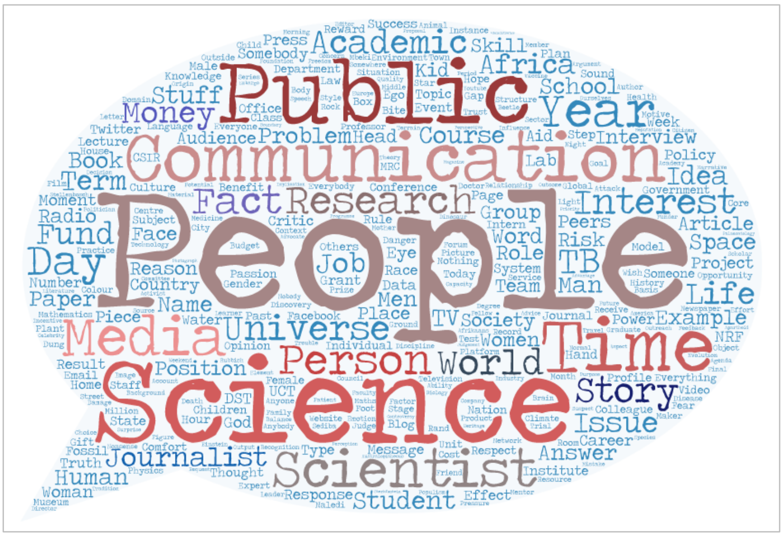
Tinyiko Maluleke writes regularly for a number of newspapers in South Africa. He has 17 783 followers on Twitter (as on 2 October 2017).

Glenda Gray was selected as one of the most influential people of 2017 by *Time* magazine.

In 2005, **Himla Soodyall** was awarded the National Order of Mapungubwe (Bronze) for her outstanding contribution to the field of science.

The African Union Kwame Nkrumah science prize was awarded to **Salim Abdool-Karim** in 2015.

Tebello Nyokong was the 2009 L'Oreal/Unesco Women in Science Laureate for Africa/Arab States and in 2016 she received the African Union Kwame Nkrumah Scientific Award.



A visual representation of the most commonly used nouns that emerged from my interviews with 30 visible scientists in South Africa