6 Science and social media: Opportunities, benefits and risks

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Making science accessible: A new mandate

Scientists in open democratic societies are under increasing strain from the state, funders and other societal actors to make scientific knowledge accessible, to decommodify knowledge and to conduct research that impacts on society and contributes to the global knowledge economy. Scientists are also required to demonstrate accountability, especially when funded by the public coffers.

This paradigm shift accelerates the demand for new knowledge and scientific content to be made visible in the public sphere (Badenschier & Wormer, 2012; Pavlov et al., 2018), with a growing demand for science communication and engagement efforts from the research community (Pavlov et al., 2018).

Indeed, funding policies in many countries around the world, including Australia, China and South Africa (Joubert, 2019), make science engagement mandatory for researchers and institutions funded by the state. For example, the National Aeronautics and Space Administration (NASA) is an independent agency of the US government, governed by the National Aeronautics and Space Act[1] which stipulates that NASA is obligated to 'provide for

1 National Aeronautics and Space Act (2010), https://www.nasa.gov/offices/ogc/about/space_act1.html and and https://www.nasa.gov/audience/formedia/features/communication_policy.html

the widest practicable and appropriate dissemination of information concerning its activities'. Similarly, the multi-node Centres of Excellence and other researchers, centres and chairs funded by the South African National Research Foundation (2018) are often obliged to dedicate a portion of their grants to science engagement. These are global and local examples of how science is funded by the public and how making research accessible to the public is part of the mandate of researchers (Pavlov et al., 2018).

Similarly, more and more individual philanthropists, corporates, private sector funders and trusts and foundations are insisting that scientists make evident the impact of their studies and that they engage with a range of publics to make their work visible. A case in point is the Wellcome Trust which under its Public Engagement Fund allocated specific funding for the use of creative approaches for this purpose (Wellcome Trust, n.d.).

In the *2018 State of the Newsroom Report*, Kruger (2018: 2) writes that there must be a balance between academic rigour in research and making the research accessible to the public: 'It is no longer feasible for a university-based journalism programme to lose itself in purely academic research.'

Researchers at universities and knowledge-based institutions are encouraged to explain the impact of their research on society, whether it be through discovery research that changes disciplinary thinking, translational research that influences policy and practice, or innovative research that can be taken to the market to generate economic activity. For example, a group of interdisciplinary earth scientists who work for the Ocean and Sea Ice section of the Norwegian Polar Institute (OSINPI) believe that through actively communicating the results of their studies, and sharing new knowledge based on evidence in the public domain, they contribute to addressing the deficit in fact-based knowledge around climate change. They use social media to continuously share information about their research and matters related to climate change, thereby trying to effect real transformation of thought in society based on scientific proof. As a small group of young scientists and researchers with limited resources, they use

different social media strategies to facilitate multi-way communication with a variety of publics, including fellow scientists and collaborators, policy-makers, funders, the media and the general public. This example provides evidence that researchers and scientists can successfully use social media channels to make knowledge visible globally, through limited resources, without relying solely on professional science communicators.

Traditional media in decline

Scientists often use the mainstream media as a conduit to reach multiple publics (Joubert & Guenther, 2017).

The media has an essential role to play in open progressive democracies to develop an informed public (Dahlgren, 2009; Gumede, 2014), amongst other priorities. However, the traditional print media and some broadcast media in South Africa are under severe economic strain due to the advent of new digital technologies and platforms, changing patterns of media consumption, declining print circulation, the closure of newspapers, and the introduction of new business models (Breitenbach, 2019; Kruger, 2017). Finlay (2018: 3) describes the 'dissolution of "the newsroom" as we know it', evidenced by the closing down of many print titles and widespread retrenchments in both the print and broadcast media in South Africa, including the proposed retrenchment of over 900 staff at the South African Broadcasting Corporation (Finlay, 2018).

The 'decimation' of newsrooms (Daniels, 2018a), the 'integration' of editorial and commercial activities (Cornia et al., 2018) and the decline in the number of specialist journalists assigned to specific beats, like science, health and education, has long been lamented (Daniels, 2018a; Thloloe, 2005), with the general quantity and quality of science reporting found to be inconsistent, unstructured and relegated at the expense of more newsworthy genres like politics and economics (Claassen, 2011; Van Rooyen, 2002). The number of specialist science journalists in the traditional media is diminishing with less than ten permanent science

journalists in South Africa in 2018 (South African Science Journalists' Association, 2018). Experienced journalists are being laid off and the degeneration of beat journalism is a global issue (Daniels, 2018a). Daniels (2018b: 4) adds that 'many retrenched journalists go into the gig economy, including doing public relations, scratching out an odd-jobs living'.

Due to resource constraints, there is a real risk that new, important scientific research may be ignored and that society may remain in the dark regarding innovative scientific developments (Badenschier & Wormer, 2012). Limited resources often result in the lack of capacity to proactively pursue stories; to report fairly, accurately and credibly; to fact-check; to explore multiple angles of an issue; and to properly investigate important, relevant viewpoints pertaining to a specific matter.

In a 'fake news' and 'post-truth' environment (Finlay, 2017), where 'science is vulnerable to abuse and distortion, especially for political purposes' (Kizer, 2018: 1) including by other scientists (Peters, 2013), in a setting where false information, science quackery and 'information disorder' is on the increase (Bourguignon, 2018), it is imperative to understand how science is sourced, assessed, selected and published, and for whose benefit. Given the constraints facing newsrooms, including the increasing power of commercial actors, advertisers, audiences, media owners, politicians and sources (Stromback & Karlsson, 2011), and the fact that journalists and editors are under significant pressure to publish new content to feed the 24-hour news cycle, there is a need for a steady flow of reliable information to newsrooms (Schudson, 2003).

As fake news proliferates, trust in the traditional media is declining, and people are becoming less believing of established sources, whilst appreciating the influence of their peers (Broniatowski et al., 2018; Hetherington in Hart & Shaw, 2001; Jones, 2004).

Understanding the tensions between scientists and the traditional media

The media creates distance between scientists and publics, does not contribute enough to the public understanding of science and does not elaborate on the impact of science on the daily lives of people, according to Nelkin (1995: 14–15) who writes that science appears in the press as 'an arcane and incomprehensible subject'. Whilst this view was expressed over two decades ago, there is still dissonance between how scientists communicate within the scientific community versus how scientists engage around scientific matters in the public domain (Peters, 2013).

Wilcox (2003) claims that science journalism norms do not sit comfortably with those of the science being covered. She states that science journalists need conflict, drama or exclusives to make science appealing to news editors, whilst scientists de-emphasise single studies and rather promote the full body of science in context. This tension is also identified by Lynch and Condit (2006) who expand on the tension between journalists who need to make stories interesting and 'sellable', on the one hand, and scientists who want stories to be neutrally reported, balanced and accurate. The lack of control over the journalistic process is identified by Peters (2013) as a major hurdle in the relationship between scientists and journalists, with some researchers opting to work with alternative models like *The Conversation* where they have final sign-off on articles before publication.

There are two major factors confronting science journalism according to Cornelia Dean, the former news editor of the *New York Times* (Dean, 2002). She claims that science journalism's reach has to be very broad, yet science is becoming increasingly specialised, so journalists cannot keep up in an age where scientific research is becoming more commercialised. Hotz (2002, in Badenschier & Wormer, 2012) believes that the relationships between science journalists and scientists 'is becoming increasingly fraught', a tenet supported by Claassen (2011).

Whilst the pursuit of the truth is a value that forms the basis of both the journalistic and scientific fields, and whilst both journalists and scientists seem to embrace the shift to an open, transparent society, given the waning trust in the traditional media (Edelman Trust, 2018) and the difficult relationships between scientists and journalists (Claassen, 2011), scientists are gradually employing direct, digital communication strategies to make science accessible to multiple publics, thereby discounting the reliance on the traditional media (Fuchs, 2014; De Lanorelle, 2017; Daniels, 2018).

Scientists are becoming increasingly skilled in media management (Franklin, 2004) and are progressively relying on professional science communication practitioners (science communicators) to share and amplify science in order to make their research relevant and visible in the public sphere (Kiernan, 2006; Stromback et al. 2012). A study focusing on South Africa's most vocal scientists (Joubert & Guenther, 2017) reveals how scientists who are also good science communicators emerge in the news and are more popular. The following science themes are covered the most in the South African print media: environment and ecology; health sciences; science and technology; zoology; astronomy; energy; anthropology and archaeology; engineering sciences; the palaeosciences; food and nutrition sciences; and physics (Patel, 2019).

The general quantity and quality of science reporting is inconsistent, unstructured and relegated to the middle pages of newspapers at the expense of more newsworthy genres like politics and economics (Claassen, 2011; Van Rooyen, 2002). Resource, time and space constraints, the declining number of specialised science journalists and the need for science journalists to write across titles and platforms in real time to feed the ongoing digital news cycle are some of the factors that impact the publication of science in the South African media (Patel, 2019).

However, despite the reduction of the number of dedicated science desks and specialised journalists, a three-month study of South African print newspapers (Patel, 2019) reveals that science made it to the front pages of two newspapers a total of eight times

during the period, with four newspapers publishing editorial columns on science-related issues.

Scientists are thus faced with the quandary as to whether to use the traditional media as a conduit to reach wider publics, whether to develop their own virtual communities or whether to use a combination of the traditional and social media.

Why should scientists communicate?

There are several reasons why scientists communicate and why they should communicate. People communicate to share information; to persuade others to do something or to change their perceptions or behaviour; to express their opinions on a particular matter; to commit to doing something; and to transform society (Searle, 1979). According to Gascoigne and Metcalfe (2012), scientists communicate to create awareness, to add value to the public discourse, to start a conversation, to share insights from their research that may be beneficial to broader communities and to create impact in society. Scientists also communicate to engage with publics, to obtain feedback on ongoing research and to serve as a catalyst for social change.

There is a need for scientists to build relationships and foster collaboration within and across research areas, as universities and research institutions encourage inter-, trans- and multi-disciplinary studies across disciplines, faculties, universities, institutions and sectors. Collaboration and inter-disciplinary research are recurring themes in the South African White Paper on Science Technology and Innovation (DST, 2019), which emphasises that talent and resources available in universities and research entities, coupled with industry support, should be harnessed to ensure that South Africa is prepared to actively participate in the Fourth Industrial Revolution (DST, 2019).

From a public relations perspective, the benefits of communicating science include enhancing the reputation of an individual researcher, or a team of researchers, attracting collaborators, students and programmes, and securing funding for research projects.

An important role of science communication is to influence policy in a country or indeed across nations. The influence of the Treatment Action Campaign and other activist organisations that used both traditional and new media forms, combined with strong advocacy and lobbying tactics, to pressurise the state into providing antiretrovirals to people living with HIV/Aids in South Africa, is well-documented in *Reporting the South African HIV Epidemic* and other studies (Muchendo, 2005; Palitza et al., 2010). This is a pertinent example of how science communication can help to effect real change in society, and in this case, result in the saving of millions of lives.

Another successful example of where prolonged science communication and advocacy has influenced policy is evident in the implementation of a new 'sugar tax' on sugar sweetened beverages that was legislated in South Africa in 2018, following the implementation of such a tax in Mexico, Chile, Denmark, France, Hungary and several other countries (Stacey et al., 2017).

In the face of tremendous pressure from the beverage industry and amidst threats of job losses and intimidation on a number of fronts, the ongoing science engagement efforts of members of a research unit known as PRICELESS SA (Priority Cost Effective Lessons for System Strengthening South Africa)[2] based in the School of Public Health at the University of the Witwatersrand, enabled the team to empower both citizens and policy-makers with the relevant information based on research, using the media and other advocacy initiatives, to make decisions about health investments in South Africa. PRICELESS SA also provides scientific information that seeks to improve the way in which resources in the country's health and related budgets are allocated and priorities are set to improve public health.

In the example described above, PRICELESS SA faced numerous challenges from the local and international beverage industry and some unions, had to contend with massive misinformation and disinformation placed in the public realm, and had

2 www.priceless.co.za

to ward off multiple threats in public and private, in their quest to impact on policy in South Africa. However, there are other instances where science communication has been less effective in changing policy, or where individuals, scientists, lobby or advocacy groups communicate to further their own agendas.

Similarly, the implementation of policies related to vaccination, tobacco, rhino poaching and energy are often made controversial in the public space, not always through a deliberation based on science, but often through the way issues are themed in the media. For example, the proposed Control of Tobacco Products and Electronic Delivery Systems Bill of South Africa (2018), which seeks to regulate the tobacco industry (including e-cigarettes and vaping products) and to remove branding on all tobacco products at point of sale, resulted in a major controversy in the media between tobacco manufacturers, the producers of e-cigarettes and vaping products, trade unions and pro-choice lobby groups, on the one hand, and the national department of health, and the National Council Against Smoking on the other.

Changing news values in a digital world

There are major shifts reshaping the science journalism landscape with the impact of new media technologies in a changing media environment recasting science journalism's familiar norms and values in unanticipated ways (Allan, 2009).

The digital disruption that we experience today impacts the news values and indices that influence what news is published, how it is assessed, selected and framed, who influences the publication of science news, and which platforms are selected for publication. According to O'Neill and Harcup (2009), it is essential to study news values because it 'goes to the heart of what is included, what is excluded, and why' some news is given precedence over others.

Badenschier and Wormer (2012) describe news values as factors that make news valuable and add that the value of news increases based on the number of news factors present in the article as well as the intensity of these factors. They attempt to develop a science

news index in 2012, with specific criteria being developed to determine what makes science newsworthy, an index which is still in development. They found that with regard to the selection of science in particular, that 'graphical material' was an important factor in selecting science news for publication and that editors had to not only select the news but also to consider the platform through which the news would be published, an additional factor that influences what becomes news in a digital era.

Whilst several news value indices have been developed over the last five decades, Harcup and O'Neill (2001) revisited Galtung and Ruge's (1965) list of ten news values and developed their own list of ten factors that make content newsworthy. They claim that particularly good and bad news make the news as do the following: news that is significant in magnitude and relevant to audiences; stories with an element of surprise; entertaining stories that focus on the powerful, the elite or on celebrities; follow-up articles; and those that fit the newspaper's agenda. Their most recent list of contemporary news values (Harcup & O'Neill, 2016) is adapted to accommodate digital and social media with the following five news values added: exclusivity; conflict; the use of audio-visual materials; shareability; and drama.

People share content depending on the news values contained in the post. Social media posts that are relevant, unexpected, and that include some form of controversy or negative consequence, and that may potentially impact on many people, are more likely to be shared (Rudat & Budar, 2015).

Social media lends itself to participatory science and to empowering citizens

Despite science and society moving closer together (Weingart, 2001, in Hargittai et al., 2018), there is limited research on how researchers and scientists use social media to communicate science (Hargittai et al., 2018), how users engage with science, research and new knowledge through scientific content in the digital sphere; and how scientists interact with their peers, the public

and other users via online and social media.

Science communications developed as a professional field after the Second World War with science communication models evolving over the last seven decades. The initial 'public understanding of science' model assumes that the public's knowledge of science is deficient because the public does not understand science, and scientists thus have to bridge this knowledge deficit by informing and educating the public through the use of unidirectional mass communication tools, in which the public is a passive receptor of information (Peters, 1996, in Hargittai et al., 2018).

A second model focuses on 'public consultation', which sees scientists engaging with the public to obtain their views on a particular issue like the efficacy of vaccines or their views on climate change. In this model, the public provides feedback on a science theme, topic or issue that is actively placed into the public domain by scientists. This could take the form of a seminar, public lecture, workshop or conference. New digital technologies like online surveys can be used to obtain the views of members of the public, for example, on new science that has been shared in the public domain. Social media polls are one way of gauging the public's response to scientific matters but are not representative samples that can be used for scientific purposes.

Newer science communication models speak to 'participatory science' which involve multi-way communication with various users, including members of the public, who, despite being non-experts, help to set the agenda, make decisions, and influence policy and knowledge production processes (Bucchi & Neresini, 2008).

It is this latter definition that aligns most with the participatory digital technologies of today (Hargittai et al., 2018). Social media lends itself to participatory science (Brossard, 2013) because there are low barriers to engagement provided that one has access to data and the internet which are still impediments in some developing countries like South Africa (Hootsuite, 2018); the playing fields are levelled for producers and users of content, and all parties have the ability to create, share and exchange information, ideas and content on similar platforms in real time.

Access to the internet and data remains a major global hurdle more than half of the world's population still not online (WEF, n.d.). The WEF (n.d.) identifies four barriers to internet inclusion: infrastructure; affordability; skills, awareness and cultural acceptance; and relevant content'. A two-year enquiry into the cost of data was undertaken by the Competition Commission in South Africa and the preliminary results reveal that the cost of data is much higher in South Africa than in peer countries (ICASA, 2019).

On social media, users have the power and the ability to decide how they would like to interact with the content and fellow users, how to filter and to manage what information they would like to receive and whether they would like to share or amplify content. Users can also control who they connect and interact with and how they engage with the content of others, for example through sharing content, liking content, or commenting on the content. According to Hargiatti et al. (2018), social media thus enables engagement though content and human interactivity, all of which can increase the number of participants engaged with science.

The terms of the debate have changed with an exponential rise in the adaptability of platforms that enable citizens and empower stakeholders to help create and reshape the news in the digital sphere (Hamshaw et al., 2017), without the reliance on the traditional media to serve as a conduit to the general public.

For example, #EarthHour[3] is widely known as an annual project of the World Wildlife Fund that aims to get people from across the world to shut down all electrical appliances for an hour in order to raise environmental awareness globally. In 2019, this campaign reached over 188 countries around the world, in part due to the impact of social media.

Social media and the internet have also transformed the conceptual framework in which people interpret, perceive and respond to risk (Chung, 2011). Social media platforms provide quick access to information in real time, serve as a sounding board

3 www.earthhour.org

and a content hub for a range of questions, proffer the opportunity to create and develop virtual communities, and enable users to connect with those of similar views (Flanagin et al., 2014).

The availability of smartphone applications and access to mobile data has changed how people search for, access and consume information in real time. At the same time, in a digital world where fake news, bots, trolls and malware have the ability to harm, to spread unsolicited content, to promote discord, and to create false equivalency (Broniatowski et al., 2018), it is essential to develop an informed digitally literate public who are savvy enough to see through misinformation and disinformation online, who can read the context within which information is shared and question the sources of the content. It is fundamental to develop digitally literate individuals who are agile enough to comprehend how issues are framed online and to understand whether fellow users are real or not. This is not an easy feat, as some social scientists believe that 'scientific knowledge both embeds and is embedded in social identities, institutions, representations and discourses' (Jasanoff, 2004: 3). If this is indeed the case, there is a risk that scientists try to order the world through how they understand it, thereby trying to regulate and systematise it according to their own views or findings (Jasanoff, 2004).

Broniatowski et al. (2018) describe the use of bots, trolls and malware to sway public perception in the vaccine debate online. See details in the section on social media risks below.

Science and social media

In the context of science engagement, social media can be described as digital networked communication channels that allow for information to be accessed and shared, and interactions to be facilitated amongst and between researchers, scientists and fellow knowledge workers, as well as with multiple other publics in the digital sphere (Collins et al., 2016). Social media can also serve as a 'complementary information network for individuals who consider being well informed as highly important' (Kuttschreuter et al., 2014: 10).

How are scientists using social media?

In a study involving 587 scientists worldwide, Collins et al. (2016) concluded that scientists across disciplines, faculties and institutions are using social media platforms to exchange scientific knowledge, although very few scientists are engaging in social media. Scientists are also using these channels as open, multi-way channels, to communicate particular aspects of research and science as a means of outreach, to increase science engagement and to encourage science literacy in society.

Collins et al. (2016) found that Twitter, Facebook and LinkedIn were used by the majority of scientists surveyed to share research and new knowledge, as well as Instagram. Science blogs were viewed by the majority of the respondents in this study (84%) to be an important online platform for science engagement.

Respondents used Facebook to share experiences in the laboratory or field, to find inspiration for outreach and science communication, to connect with fellow researchers and to correct fake science news in the public domain. Whilst this study found that Facebook could play a role in bridging the knowledge deficit and encouraging consultation on a particular topic, 'not many respondents found Facebook to be a suitable platform for discussion or to develop scientific literacy' (Collins et al., 2016: 5). They also did not find Facebook useful for communicating with the general public or with fellow researchers.

However, the study found that scientists spent between 15 and 60 minutes on Twitter every day on 'scientific tweeting', described as a tweet based on a science subject, created or shared by a scientist, that usually included a science-related hashtag. These scientists were found to tweet about research within their own field, particularly when they were participating in a conference or event, where they generally used the hashtags created by conference organisers. Scientists in this study found Twitter to be a useful medium for engaging with fellow scientists, the public, other audiences and the media.

The majority of scientists in the Collins study found science

blogs to be informative, with 89% of the scientists surveyed agreeing that blogs were valuable in explaining science to the public. About half of the respondents claimed to have written their own blogs (Collins et al., 2016).

This study differed from the results of a US study into how young adults use social media for science communication conducted by Hargittai et al. (2018), which found that most young adults in the US used the Facebook platform, followed by Twitter, with almost 40% of the respondents using both channels. They found that 44% of young adults shared science and research content via Facebook compared to 10% of Twitter users. The study also revealed that Twitter was a popular medium through which to share science and research content, particularly during and after events and conferences.

A slightly different approach was adopted by Pavlov et al. (2018), a group of researchers from the Ocean and Sea Ice section of the Norwegian Polar Institute (OSINPI), who provided an account of how they have successfully used social media over a three-year period to reach young audiences through an essay in the *Bulletin of the American Meteorological Society*.

Comprised of about 20 members, the OSINPI group engages with fellow scientists and the general public through Instagram, Twitter and Facebook. Instagram was deliberately selected as the first medium of choice by the team as it is a visually appealing medium that attracts younger audiences and connects with younger people emotionally. Instagram lent itself to the project, as the OSINPI group had a range of good quality visuals to share, with fieldwork and educational posts proving to be popular content. Selected posts were amplified through collaboration with similar entities and influencers like *National Geographic*, who were tagged in some posts and who shared some of the content via their respective social media channels.

The second medium of choice for the OSINPI group was Twitter, selected because of its appeal to older, engaged audiences that included members of the media, fellow researchers and scientists, influential politicians, policy-makers and consultants. The

Twitter posts contained new information and breakthroughs and the platform was particularly used for live tweeting from events and announcements. The use of hashtags and keywords to better engage with the public was also a successful strategy employed by the group.

Facebook was also included in the OSINPI social media strategy due to its wide reach and ability to connect personally with colleagues, friends, and like-minded groups. Posts related to the achievements of scientists, or news related to researchers, including profiles, were shared the most on Facebook.

It is important to distinguish content by platform (Yeo, 2016). Whilst Twitter may be good for expert debates about science and research, Facebook may be a better medium to bring science closer to selected communities, whilst Instagram may encourage visual engagement. In all instances, it is important for the content to be captivating and tailored to the different audiences using these platforms.

Pathologists are also using social media for collaboration and networking purposes and for sharing information with the general public. This is according to a study by Gardner and McKee (2019), which stipulates that there are more than 4 700 pathologists and pathology-related accounts on Twitter. However, pathologists are also using Facebook to share educational content like useful case studies, resources and articles, with in-depth discussions on particular cases taking place in Facebook groups. Similar usage patterns can be observed in the Early Southern Sapiens Facebook study group,[4] an online community led by Professor Christopher Henshilwood and comprising of hundreds of scientists, researchers, communicators and interested parties from around the world, with the primary objectives of trying to establish when, why and how humans first became behaviourally modern and what it means to be human.

Similar to the OSINPI group, selected images are shared by pathologists on Instagram, and Twitter is used for sharing

4 https://www.facebook.com/groups/SouthernSapiens/

content from meetings and events. However, Gardner and McKee (2019) emphasise the benefits of using YouTube for teaching and educational purposes. They describe the use of this social media platform as transformative as it enables communicators to become more efficient as educators, provides the ability to share content across the world, even in 'medically underserved areas', and when incorporated into official curricula, allows the sharing of video content with students and colleagues, which frees up time to conduct further research.

The use of smartphones and 'digital photo-microscopy' allows for high resolution images to be taken with a smartphone and to be shared digitally in real time, and in so doing to traverse the barriers of time and distance when working on pathology cases that require immediate review (Gardner & McKee, 2019).

Whilst no comprehensive study exists in South Africa as to how researchers use popular social media, a study by Onyancha (2015) determined that scientists at research-intensive universities in South Africa who used social media platforms like ResearchGate were more likely to obtain coverage, to register a higher impact score and have their universities feature in the global university rankings.

In terms of popular social media, there are project-specific examples that offer some insight into how scientists use popular social media to communicate science. For example, a study by Mudde (2019) explores how South Africa's two most visible scientists, Professors Lee Berger and Tim Noakes interact on Twitter. The research establishes that both scientists try to be accessible and transparent and use Twitter to inform, educate and sometimes entertain their followers on matters related to their respective disciplines. In another instance, research into how the Square Kilometre Array (SKA) Telescope was represented on Twitter over a period of a year found that whilst most tweets were from large media organisations and leading science journalists, there were substantial opportunities for high-profile individual users to shape the discourse around the SKA (Gastrow, 2015).

Creating compelling social media content

Whilst scientific data related to social media metrics is freely available, the psychology behind why some users engage with some content and not others is scant (Hwong et al., 2017) and there is a need to research deeper forms of interaction, including why people click through to some articles and not others, or spend more time reading some blogs at the expense of others. Further, whilst social media enables users to create their own content, and interact with science content by retweeting, sharing, commenting and liking content, there is a need for research to examine how users engage with content and with fellow users online (Hargittai et al., 2018; Hwong et al., 2017). This extends to how users really engage with content, for example, by clicking through a link to find out more about the subject and also whether this engagement translates to influence or behavioural change over time.

On social media it is important to be authentic, different, respected and influential. The development of a unique persona and voice, coupled with humour and delivering content that people really want, are key considerations for developing any form of social media (Hootsuite, 2018). It is important to 'focus on creating mutual value instead of just trying to sell more stuff, make it easy for people to engage online and to use digital tools to keep the conversation going' (Hootsuite, 2018: 9).

Pavlov et al. (2018) advise that good quality audio-visual material, coupled with clear, concise, high quality, clever text, tailored per platform, make for good content to develop audiences. Content is key, should be planned in advance, and can include posts related to science education, laboratory or fieldwork, publications, team achievements, relevant events, breaking news, and historical posts like 'Throwback Thursdays' or 'Flashback Mondays'.

The ability of scientists to freely express their views, with little or no institutional limitations is also described as a key factor for a successful campaign by the OSINPI group. They also advise on working in teams, sharing experiences, and collaborating

with communications units in research institutions and universities to develop professional communication strategies. They explore creating complementary social media accounts to amplify campaigns and to boost them where appropriate through page advertisements, promotions and other forms of paid-for content.

In 2017, Hwong et al. (2017) conducted psycho-linguistic research into why some space science posts are more appealing than others. They examined NASA's social media accounts (31 million Twitter followers and 21 million Facebook likes in 2019) and ascertained at the outset that space science is visually appealing and that the images and audio-visual material from space automatically lends itself to social media. However, they also found that aside from good, high-quality images, the visual description of the images, and content that evokes anger, authenticity and anxiety, makes for more engaging content on Facebook. In comparison, the top features for compelling and engaging space science in Twitter content are found to be visual elements like photographs, gifs and videos, and posts that include URLs and hashtags. Remarkably, Twitter posts that hint at some sort of 'certainty' are found to be more engaging by users.

The development of future social content will be rich content that includes social television for mobile devices, live broadcasting on social media, but it is all dependent on whether users have access to the internet and sufficient data. Access to the internet and affordable data was recognised and deemed to be a priority for South Africa to advance its developmental priorities according to the Minister of Communications and Digital Technologies, Ms Stella Ndabeni-Abrahams.[5]

An example of a social media campaign that delivered a high engagement rate[6] was a university-based campaign developed by communications professionals and scientists and doctors from the Donald Gordon Medical Centre in Johannesburg to announce

5 Minister of Communications and Digital Technologies, Ms Stella Ndabeni-Abrahams was speaking at the 2019 Digital Economy Summit in Johannesburg on 5 July 2019.

6 This refers to engagement with the content in the form of reactions, comments and feedback.

the results of the first intentional liver transplant from an HIV-positive mother to her child in October 2018.[7] The overall objective was to inform the public about the option of transplanting an HIV-positive liver into HIV-negative individuals in order to save lives and to encourage more people to donate their organs in South Africa. In total, 22 social media posts were developed for Facebook and Twitter, and together with a YouTube video, reached over 200 000 social media users. Of these, about 15 000 users engaged with the content within three weeks (measured through clicks, shares, likes and comments), with 58% of the users being female and 42% male. The engagement rate for the entire campaign was calculated at a rate of 6%, which is an extremely high rate for a social media campaign, as engagement rates for most campaigns average between 1% and 2% (Khumalo & Minors, n.d.).

The benefits of using social media

Professional science communicators, scientists and researchers, advance a multitude of benefits for using social media to communicate science.

Pavlov et al. (2018) view social media as an opportunity to bridge the gap between science and society, to engage the next generation of scientists, to reach out to the public and to empower policy-makers so that they can make informed decisions that will help to shape a better future for all.

Social media empowers citizens who are able to actively produce their own content, to engage with content that they want to receive, to curate content and to limit or expand on content. Users have the ability to decide on what content they want to receive and from whom, through which platform, and to become their own active gatekeepers as they select what content they want to share with their respective communities.

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7 http://www.wits.ac.za/news/latest-news/research-news/2018/2018-10/worlds-first-intentional-hiv-liver-transplant.html

Social media also enables information to be shared in real time and facilitates rapid engagement on science and research between scientists and the public (Bik & Goldstein, 2013).

According to the respondents in the Collins et al. (2016) study, the ability to reach a wide, engaged and diverse audience, the ease of communicating in a short message format, the ability to project a view or share a message in real time and the accessibility of Twitter as a medium are some of the reasons why scientists feel that Twitter is an excellent medium through which to communicate science. The respondents in this study also claim to benefit from networking and communicating with other scientists through Twitter, as it provides access to issue publics that proffer multiple views from across the globe, which can be easily shared with fellow scientists, the public, science journalists and other relevant social actors. Twitter is also inexpensive and can be used in resource constrained environments (Pavlov et al., 2018).

However, the cost of interacting on social media, for example, through exchanging private information for the use of a platform or social media application, is viewed by many critics as a major risk borne by users who are often oblivious of the risks attached to sharing their personal data. In July 2019, there was a major global uproar around the use of an application called FaceApp, a fun online application that allowed users on Facebook to determine how they would look as they aged. This seemingly harmless application was developed in Russia and was accompanied by a set of terms and conditions which granted the developers full rights in perpetuity to all images uploaded to the application, for the developers to use as they deemed fit, in any way, at any time across the globe. On closer inspection, this does not seem to be a fair exchange between users and developers, which raises many questions related to cyber ethics and cybersecurity in the digital space.

A tangible benefit of using social media is put forward by Pavlov et al. (2018) who demonstrate how social media is used to calculate 'alternative metrics' (or altmetrics for short). Altmetric services track what impact a study has on social media and the traditional media, and in the case of the former is calculated based

on mentions on Twitter, shares on Facebook and the number of people who read the stories on selected academic social networks. The OSINPI group tracked 15 articles and found that 'social media accounts clearly boost the metric scores of research group publications and the visibility of the research both within and beyond the scientific community' (Pavlov et al., 2018: 1). This resulted in multiple spin-offs for the scientists and researchers, including approaches from the traditional media to amplify the news and stories shared on social media.

There are other benefits to using social media including that of experiencing 'live science' as it unfolds and develops (Jepson, 2014). For example, in 2017 Professor Lee Berger and Professor John Hawkins, both associated with the University of the Witwatersrand, developed a live blog and Facebook page called The Daily Life of an Explorer[8] which enabled viewers from around the world to track, follow and engage in real time with scientists and explorers who were excavating for *Homo naledi*[9] in the Dinaledi Cave, part of the Rising Star Cave System located in the Cradle of Humankind just outside of Johannesburg, South Africa. The blog included images, live video coverage, podcasts, interviews with experts, scientists and explorers and opportunities for people to engage directly in real time with scientists on site. It also enabled users to share in the 'Eureka! Moments' when new hominid fossils were discovered or the tense moments when explorers found it difficult to squeeze through parts of the cave.

Another example of using new, creative media technologies to make science accessible to wider publics was the development of a free mobile application by Professor Berger and his team in conjunction with the Perot Museum of Nature and Science in Texas, USA, which allows users, scientists and the general public to enjoy a virtual experience of the Dinaledi cave system in six different languages, using cardboard 3D glasses.[10]

8 https://www.facebook.com/dailylifeofanexplorer/

9 http://www.wits.ac.za/news/latest-news/research-news/2015/2015-09/homo-naledi/a-new-species/

10 https://www.wits.ac.za/news/latest-news/general-news/2018/2018-10/

The barriers to using social media

Some scientists are reluctant to use social media to communicate science as they have little knowledge of social media, do not know how to use it, do not to have the time to engage on social media, or see it as a frivolous, unprofessional activity that is age-based (Collins et al., 2016; Gardner & McKee, 2019; Pavlov et al., 2018). Other reasons put forward for shunning social media include the insufficiency of the medium's scientific validity, an aversion to the content being shared, the risk of being exposed to wide audiences, the erosion of privacy online and a dislike for various social media formats, especially Twitter's microblogging format or Instagram's obsession with vanity pictures.

In South Africa and the rest of the developing world, one of the greatest barriers to using social media is the lack of access to data and fast internet services, particularly outside of urban areas.

Social media risks

'It is important to question who holds power in society, who takes the important decisions, who owns the basic resources, who is considered influential, who has the reputation to influence and change society, who is an opinion maker and who defines the dominant norms, rules and values' (Fuchs, 2014: 7). This speaks to both the traditional and social media as we determine how these media platforms benefit some, whilst disadvantaging others. Fuchs advocates for the need to develop a society that is universally beneficial to all.

The influence of players in the digital sphere was revealed in a study by Broniatowski et al. (2018) who sought to better understand how Twitter bots and trolls promote online health content. In the study, 'bots' are described as 'social media accounts that automate contention promotion', whilst 'trolls' are described as 'individuals who misrepresent their identities with the intention

wits-and-perot-museum-launch-virtual-reality-app-of-dinaledi-cave.html

of promoting online discord' (Broniatowski et al., 2018: 1).

The study found that through the amplification of anti-vaccine messages by false social media accounts, content around vaccinations was polluted, and public consensus on social media was eroded. Another strategy was to represent both sides of the debate, whilst inherently promoting one perspective, similar to strategies employed amongst certain political groups in national election campaigns in the United States[11] and in South Africa.[12]

Broniatowski et al. (2018: 1) explain how 'health-related misconceptions, misinformation and disinformation spread over social media pose a threat to public health'. As social media users are exposed to erroneous information about vaccines, they take time to digest the information or to explore it further, and in so doing delay in taking the required action to vaccinate, thereby putting themselves and entire populations at risk. The study analysed a set of 1 793 690 tweets collected over three years and included a qualitative study of a Twitter hashtag which deliberately politicised the issue and created dissonance in the Twitter sphere. The #VaccinateUS hashtag was traced to Russian troll accounts linked to a company associated with the Russian government that was known for influencing issues online.

The study found that about half of the tweets about vaccinations analysed contained anti-vaccine sentiments, and that people were more likely to trust information on the internet and in social media groups than to trust their own healthcare providers or public health experts. The study concluded that 'whilst bots spread malware and unsolicited content in the form of anti-vaccine messages, Russian trolls promoted discord' online (Broniatowski et al., 2018: 1).

Similar considerations should be given to science quackery, misinformation and disinformation campaigns on social media, some of which relate to climate change, medical conditions and

11 https://af.reuters.com/article/worldNews/idAFKCN1QF29E

12 https://www.dailymaverick.co.za/article/2019-03-06-beware-of-the-bots-and-the-trolls-in-the-polls/

even water quality in South Africa (Kubheka, 2017; Volmink, 2017).[13]

Another threat is posed through the social media conglomerates that own the large social media networking sites. A key finding from the *#SocialSA_2018* report by Patricios and Goldstuck (2018) reflects that influencers on social media can help recruit audiences and turn users into advocates for a course, but that these influencers are not necessarily celebrities. They also question how companies and organisations can win back audiences and communities grown and developed on major social media networks, and 'migrate' them back to in-house networks. This is because the larger social media networks now want organisations to pay to advertise to the communities that the organisations helped to build over time. Organisations have no control over the algorithms used by the major social networking platforms, no influence over the management of these platforms and no access to the data derived from the communities that they helped to develop on social media.

The Fourth Industrial Revolution brings with it increased interaction between humans and artificial intelligence (AI) in the form of machine learning, chat bots and content generated by AI, which may bring with it its own challenges, especially those related to issues of privacy, governance and ethics.[14]

Who is using social media?

Data published by the Pew Research Centre (2019) shows that 98% of young adults (i.e. 18–29 year olds) in the US use the internet, whilst 88% use social media. About half of all young

13 The Centre for Science and Technology and Mass Communication held a conference titled 'Quackery and Pseudoscience' in 2017. Several videos that speak to this statement are available: http://www.censcom.com/index.php/conferences/conference-videos. See also Statement by Professor Jimmy Volmink, Dean of the Faculty of Medicine and Health Sciences (FMHS) at Stellenbosch University (2017): https://www.sun.ac.za/english/Lists/news/DispForm.aspx?ID=5088

14 The 4IRSA partnership's Digital Economy Summit: www.4irsa.org

adults in the US obtain their news online, with 32% indicating that social media is a major news source (Gottfried & Shearer, 2016). Only 5% of young adults obtained their news from newspapers, 14% from radio and 27% from television (Mitchell et al., 2016).

Data released by the US's National Science Board (2018), indicates that 81% of young adults use the internet as their primary source of science and technology information while 83% use it as their primary source to learn about science and technology. The high use of the internet and digital channels to access science and technology news is corroborated by a study undertaken by Hargittai et al. (2018), which indicates that 96% of young adults in the US turn to the internet for information about science and research, and almost two-thirds do so weekly. The latter study goes one step further in trying to measure science engagement online. It determined that more than 80% of the young adults surveyed, clicked or commented on information related to science and research, with content related to health and fitness being extremely popular.

Social media penetration is the highest in North America with about 70% of the population connected, followed by Europe (54%–66%), Asia (64%), and southern Africa (31%) (Hootsuite, 2018). On the other hand, in terms of mobile connectivity, the number of mobile connections in southern Africa in relation to the population is 147%, which is way above the global average of 112% and North America (103%) (Hootsuite, 2018).

In terms of active users of key global social media platforms, Facebook is the largest networking site in the world with 2.1 billion users (Hootsuite, 2018). It is the easiest social network through which to reach mass markets, with steady engagement from fans and followers. However, it must be noted that the rate of engagement does not necessarily translate to influence or behavioural change (Sanne & Wiese, 2018). A literature review by Schein et al. (2011) also concluded that the impact of social media on the awareness of issues and behavioural change related to healthcare communication is still to be determined.

Like Facebook, LinkedIn can also be described as a social networking site that seeks to connect professionals, with 260 million users around the world in January 2018 (Hootsuite, 2018).

Social media platforms that are renowned for their visual and audio-visual content are Instagram and YouTube. Instagram, with 800 million users, is used to share visual material, especially images and short video clips, and enjoys a higher engagement rate than Facebook (Hootsuite, 2018). On the other hand, YouTube a video sharing site, has 1.5 billion subscribers globally (Hootsuite, 2018).

With almost 7 000 tweets being sent per second, Twitter is a microblog with 330 million users (Hootsuite, 2018) that is used to engage on events, for live tweeting and for sharing or amplifying news, politics and related content, with limited engagement.

Finally, blogs are usually theme or topic-specific mini websites like BlogSpot or Wordpress, where people can create and publish lengthier pieces. See section on alternative media below, for more information on platforms like *Medium* which can be described as a 'blog for blogs'.

The South African landscape

With a population of about 57 million, South Africa has a 54% internet penetration rate which amounts to about 31 million internet users (January 2018 data), up 7% from 2017 (Hootsuite, 2018). There are 18 million active social media users in the country, with a 20% year-on-year increase in subscriptions to various social media platforms (Hootsuite, 2018). There are 38 million unique mobile users in South Africa, of which 16 million are active social mobile users. In terms of device usage, 95% of South Africans have mobile phones, of which 60% are smart-phones (Hootsuite, 2018).

Facebook is the most popular social media platform in South Africa, in use by 46% of the South African population (about 18 million users, of which about 14 million access Facebook via mobile devices) (Hootsuite, 2018). The introduction of Facebook Lite, which has been adapted for the South African context, has

made it easier for people to access this social medium in recent years (Patricios & Goldstuck, 2018). This is also the most popular social media platform for advertising and rivals the traditional broadcast media to reach a broader audience. Communication is two-way or multi-way and can be measured precisely.

There are about 8 million South Africans on Twitter and this is the application that generates the most debate on politics, the economy, hard news and crime. It boasts strong user engagement and is the social medium of choice that facilitates communication, engagement and public discourse (Hootsuite, 2018).

Instagram is growing steadily in South Africa with just over a million users and is the social medium most used by young people (Hootsuite, 2018). There are about 6.1 million South African LinkedIn users. It must be noted that there have been dramatic declines in the use of Pinterest, Google+, WeChat, WhatsApp and Snapchat in the country (Patricios & Goldstuck, 2018).

Integrating traditional and social media

Developing an integrated science communications strategy

Scientists are adopting blended approaches and are combining the use of traditional and social media to make their research visible. For example, a scientist who has published a research paper will create a mini-website online as a hub on which to host the academic paper (or links to the journal), a media release, fact sheets, images, video material, podcasts, captions, background information on the scientist and collaborators, and other information, thus making use of owned media channels to host the news.[15] These materials can then be shared via social media or a link to cloud-based file storage services to reach out to and to create awareness of the research amongst science journalists, fellow scientists, the general public and other social actors.

At the same time, a traditional media advisory can be shared

15 For an example of a basic microsite, visit https://www.wits.ac.za/homonaledi/

with science journalists, news wires and online press offices like the American Association for the Advancement of Science's Eurekalert! site. Scientists can write an opinion piece for a weekly newspaper like the *Mail & Guardian* in South Africa, which has a small circulation but a quality audience with thoughtful readers who will engage with the subject matter, or the *Sunday Times* which, with a circulation of 240 219 and a potential readership of 1.2 million, remains a high-impact publication in South Africa (Breitenbach, 2019). This is the same for traditional radio and television interviews, specialist documentary programmes or in-depth news features on news programmes like *Carte Blanche*. So, how are integrated science communications strategies developed and executed?

Six key elements should be considered when planning an integrated science communication and engagement strategy. It is important to determine the aim, objectives or goal of the communication; to identify the audiences with whom to engage; to develop the messages to be conveyed; to consider the medium to be used as a conduit to reach select audiences; to agree on the science communication and engagement activities to be implemented; and to identify upfront how to monitor and evaluate the communications activities.

These elements are as important when considering integrated science communications that include digital media (online, new and social media), which include all the elements described above, although with a different emphasis on some aspects rather than others.

Goals and objectives

It is essential for the aim, objectives and goals of an integrated science communication plan to be established upfront, as it speaks to what is to be achieved, how it is to be achieved and by when it is to be accomplished. It provides direction for how messages are developed, which media are to be used, which channels and platforms are best suited for use, and which science communication and engagement activities are implemented.

Audiences, publics and communities

As in traditional science communication, it is important to understand with whom it is important to communicate, and to understand the demographics, geographies and psychographics of the potential audiences. In the digital sphere, through access to rich data, tracking and analysis, audiences can be highly segmented based on their digital footprints, and with the necessary permissions, their content preferences.

The ethics involved in data mining, collection and analysis, must be considered in line with the consent of users who should first grant access to their respective online identities and digital footprints. At the same time, social media allows for the growth and development of like-minded communities to share relevant information, to increase engagement, to develop collegiality and to congregate on topics and themes of shared interest.

Messages and content

The ability to tailor research messages and science content to individuals online or via specific social media platforms is effective and powerful, based on the digital profile of users. It differs from the key messages used in the traditional mass media where one set of messages can be shared across print and broadcast platforms. For social media, content per user or user group must be tailored for each online, digital or social media channel selected for publication.

There is also a need to generate multimedia content that can be adapted for use across different platforms. The content must be newsworthy, topical, should tell a story and, where possible, should include creative multimedia material that can be adapted across all platforms. The development of multimedia content allows for the ability to show and tell a research story, to interact with users, and to use visual content to create impact.

However, fundamental differences exist in how the science is communicated, how engagement occurs, the level or depth

of interaction with the content and other social media users, the immediacy of the interaction, and the ability of the science communication or engagement activities to effect change. For example, whilst traditional media allows for feedback through letters to the editor or calls on radio talk shows, there is very limited engagement on issues related to science that features in the traditional media. This engagement is often staggered in newspapers, with feedback often only published if it is a major breakthrough, a new discovery or if it impacts on a large populace.

The medium matters

Scientists now have the ability to consider the traditional media as a conduit to make their knowledge accessible in the public sphere, and to combine it with a proliferation of social media networking tools. Researchers are able to use creative multimedia strategies to create their own content, to build their own communities and to communicate directly with audiences, fellow researchers and the general public in a personable way, across platforms. Scientists and professional science communicators are increasingly becoming digitally savvy.

Science communication tools and activities

The digital tools available to scientists and science communicators can largely be categorised using a model developed by Dietrich (2014) called the PESO model. The model encompasses four categories: paid, earned, social and owned media.

Paid media refers to digital and online advertising, native advertising, paid for or promoted digital content like sponsored tweets, Facebook or LinkedIn posts. The earned component speaks to the traditional public relations model in the digital sphere and includes media and influencer relations. The social media channels comprise of the myriad of available channels that can be used to share science and to make science accessible in

the public sphere, with the most popular current social media platforms being Facebook, LinkedIn, YouTube, Twitter and Instagram. Finally, the owned media channels are those which are owned by research institutions and universities like websites, newsletters and social media channels, which are used to host or distribute content that is crafted and developed in-house and tailored for each audience and channel.

The ability to tailor science content and to adapt it to a variety of audiences across multiple platforms is a major benefit for scientists and science communicators, affording them direct control over the initial content, guaranteeing publication and distribution, and allowing for the ability to track users and content through analytics and other software tools that provide insight.

Monitoring and evaluation

It is easier to monitor and evaluate quantitatively digital and online campaigns through media monitoring agencies, Google analytics, online dashboards, social media reporting and online analysis tools. The complexity of social data also needs to be appreciated and disaggregated so as to develop user insights rather than just metrics. However, the way in which social media is evaluated using current metrics may soon be outdated, with organisations now looking to link the outcomes of social media campaigns to tangible benefits like increased collaboration amongst peers, lower promotion costs, increased funding and talent attraction (Patricios & Goldstuck, 2018).

Whilst qualitative monitoring and evaluation provides detailed insight into the success of campaigns or projects, it remains expensive.

Alternative media models

As scientists struggle with traditional media to publish their science news, alternative media models have developed over the years to

make research accessible to a range of publics. *The Conversation*[16] is one such example, which is an independent source of news from the academic and research community, delivered directly to the public. It develops content in partnership with experts and researchers, usually attached to a university or research institution (which sometimes funds the platform) and then publishes and syndicates that content across its own platforms but also shares it with other traditional and online media.

There are benefits of these forms of media, including that the publications can produce quality, multimedia science news in partnership with academics and researchers, thereby creating a safe space for academics and researchers to engage and to jointly produce accurate content that is compelling and engaging to popular audiences. It also provides an opportunity for scientists to sign off their work before it is published, thereby reducing the traditional tension between scientists and journalists.

Issues related to the independence of these alternative media remain, particularly in terms of funding from universities, science agencies and the like, but similar tensions have been identified in the form of influence from advertisers and owners in the past.

A similar model is *Quartz.com*[17] founded in 2012 by journalists, a platform which carries science and technology news that is 'creative and intelligent journalism' told through stories and tailored for readers. This platform has subsequently been funded by the corporate sector.

Medium[18] is another example of online social journalism, which includes a mixture of people, publications and blogs and which is best described as a 'blog host' that offers quality content and pays authors depending on the number of people who engage with the content. *Medium* is funded through subscriptions, native advertising and the sponsorship of some article series.

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16 www.theconversation.com/Africa

17 https://qz.com

18 https://medium.com/

Future disruption

The advent of the Fourth Industrial Revolution is set to dramatically change how humans interact with technology, how we express ourselves, how we communicate and how we engage with Society 5.0.

Whilst digitalisation has already transformed newsrooms and the way in which science is communicated, the potential for further disruption through transformative technologies such as artificial intelligence, big data, automation and crypto currencies is immense. These new technologies have already, and will continue to impact our lives and the world of work as we know it today – it will reshape how we live, work, and interact with each other.[19]

For example, algorithms and artificial intelligence are already determining online advertising in publications, writing and curating digital content, and guiding online promotions. Native advertising and product placement are now automated across digital spaces, which pose a risk to digital communication. Future science content on social media is likely to include rich content, coupled with podcasts, infographics, animation, footage from drones and Go Pros, in real time. Access to open and live science is also in demand.

Science communication lends itself to interactive mobile applications and virtual, augmented and mixed reality experiences, which are already in existence. The use of edutainment, gaming, and reality shows are on the cards, along with new, interactive platforms.

At the same time, given the risks associated with these new content types, innovative creative media technologies, and multiple platforms, some of which are known, and the majority of which are still to be realised, there is a need for the development of ethical guidelines to combat bots, trolls and potential 'weaponised' communication. This includes the development of new privacy laws to protect digital footprints and social media users, as well as

19 www.4irsa.org

policies to distinguish fact from fiction, and applications to distinguish science from quackery, and scientists from bots.

Conclusion

The Fourth Industrial Revolution brings with it the opportunity to use digital technologies that will enable the creation of innovative media platforms, the ability to develop rich, science-based creative content and the confidence to share it with multiple publics at a lower cost than through the use of traditional media. At the same time, the contextual realities of South Africa and the continent where the future of work is uncertain, where inequality remains rife and where the digital divide has the potential to further isolate communities who have little or no access to data or the internet, must be acknowledged.

The various pressures placed on scientists to make research and knowledge accessible emanate from various social actors, including funders. There are several case studies that demonstrate the benefits of communicating science, with one of the key advantages being the ability to empower citizens by having them participate in science.

At the same time, the changing media environment and fluctuating news values in a digital world dictate that the traditional media no longer serves as the sole conduit of science to the general public. This makes it necessary for scientists to find alternative ways of communicating to multiple publics, despite the tensions that may exist between scientists and the media. Safer options include using hybrid media outlets like *The Conversation* that encourages academics and journalists to partner to develop factual news that is accessible to lay publics. Other choices include the use of academic social media like ResearchGate, as well as closed Facebook and WhatsApp groups that are shared by like-minded scientists, issue publics or persons interested in a particular research topic, theme or study.

There is a steady uptake in the use of social media to communicate science across the world, including in South Africa, where

an integrated approach to science communication is proposed. This includes the use of the traditional media and social media to make science visible in the public sphere. There are many case studies both locally and abroad of how integrated science communication has succeeded through the consolidation of paid, earned, social and owned media.

However, some scientists remain reluctant to use social media as they do not understand the platforms, how they work or are sceptical about their scientific validity. On the other hand, some of the benefits put forward include bridging the gap between science and society, empowering citizens in real time, demonstrating social impact and contributing to democracy.

Many social media risks are linked to media ownership, power and politics in society, which pose risks to science, scientists and social media users. The few conglomerates that dominate social media like Facebook and Twitter are powerful entities that have access to the private data of millions of users. This brings skewed power relations between media conglomerates and social media users, especially with regard to risks related to governance, privacy and ethics in the digital sphere. The use of artificial intelligence and machine learning driven by algorithms have the ability to power bots and trolls, to influence the content to which users are exposed, to sell data to advertisers, to manipulate how users think, and what they think about, amongst other risks.

There are endless opportunities to use new creative multimedia technologies to facilitate science communication across multiple platforms in real time across physical and virtual boundaries. However, there are concomitant risks to science and science engagement, some of which are known, and others which we can only predict.

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