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Contents

From the guest editor

Science and technology is the primary productive force, the most important driving force of economic and social development, and the decisive factor in the competition of national strength. Modern science originated from Greece. Through its continuous integration with social and economic development, science and technology has spread into different civilizations and developed into different forms of science culture. The traditional Chinese culture believes in the beauty of diversity. Culture is splendid because of diversity, and is prosperous because of communication. This is also true for science culture. Science cannot develop without social context. The production of scientific knowledge is a lively process of integrating human nature and local culture, rather than an absolute truth sitting in the corner, waiting to be discovered. It is these real circumstances of knowledge production that contribute to the diversity of global science culture, a concept that is gaining increasing recognition, attention and appreciation.

In this context, the National Academy of Innovation Strategy (affiliated to the China Association for Science and Technology) successfully held the Science and You International Conference in Beijing on 15–17 September 2018 together with Université de Lorraine. Under the theme of ‘knowing, sharing, caring: new insights for a diverse world’, the conference calls for a new perspective to explore this diverse world, to understand, share, advocate and promote the spirit of science, and to build a scientific outlook that features the transition from knowledge to culture and from global unity to pluralism and diversity.

The topic of this issue is ‘diverse science cultures’. Under this topic, we have collected the special report delivered by Academician Han Qide at the Science and You International Conference and other academic papers, which explore the topic from different dimensions, such as science culture, science communication, public understanding of science, cultural authority of science, and science and society. From multiple perspectives and positions, the papers depict science as a polyhedron with changeable forms when viewed from different angles. Through an exploration of science culture in China, West Africa, Japan, and Canada, they not only present to us the diversity of science culture, but also seek to establish the pattern of science culture and set the direction for its future development.

Donghong Cheng
Chinese Association of Natural Science Museums, China

Cultures of Science 2019, 2(1): 5–8

Scientific culture: Its Western origin and its context in modern China

Qide Han

Peking University, China

Distinguished guests, dear colleagues,

Today, the 2018 Science and You International Conference is being held in Beijing. Scholars from around the world will exchange ideas under the theme of 'Knowing, Sharing and Caring: New Insights for a Diverse World'. This in itself reflects our shared desire to promote communication and interaction among different scientific cultures. Now, I would like to offer some of my observations on the features of scientific culture in China today.

During the 16th and 17th centuries, natural philosophers in Europe began to combine rational exploration with empirical research to form new scientific methods and express the ideals, beliefs and purposes of the scientific community. It was against this backdrop that a new culture within the scientific community—scientific culture—came into being. It included a new set of values, thinking patterns and behavioural and social norms developed by the scientific community based on scientific activities.

The rapid advance of modern science, especially the combination of science and modern technologies, has stimulated productivity growth, leading to closer relationships between science and society and continuous expansion of the science–society interface. Scientific culture, which is created within the science community, has been extended to all areas of society. As a result, the public is increasingly convinced that science provides human beings with the wisdom to understand nature, and rational inspiration to explore the future of the world. With widespread public recognition of the value and significance of science, scientific culture has become an important part of popular culture. Conversely, the diversity of social culture has also had an impact on scientific culture and shaped its various features.

Since the introduction of modern science into China, scientific culture, which originated in the Western scientific community, has blended with and become deeply rooted in traditional Chinese culture and has developed Chinese characteristics.

1. The different cultural backgrounds of Chinese and Western scientific cultures

Scientific culture was born in the West. As early as in ancient Greece, the free people's pursuit of pure knowledge and the 'use of useless knowledge' fostered and shaped both curiosity about nature and the rational tradition in Western culture. The establishment, development and perfection of metaphysics provided useful mental training for the further pursuit of the establishment of a strict and self-consistent system of logic. The debate between nominalism and realism in Christian scholasticism paved the way for the birth of modern science. Modern science, with paradigms to do with seeking truth, experimentation, falsification and quantification, formed its own cultural traditions, which gradually became the ethical norms and values of the scientific community. Since then, modern science has fully demonstrated the 'power of knowledge' with its convincing and persuasive achievements. Science has changed the world, and knowledge has stirred the hearts of people. Scientific culture has penetrated into every corner of society and has come to represent the mainstream values of Western society.

Similarly, in the process of understanding and transforming the natural world, the Chinese people also fostered a distinctive cultural tradition. A respect for the laws of nature and an emphasis on holistic thinking, systematic thinking, dialectical thinking, the unity of humans and nature, meditation and implicit expression are important features of the traditional Chinese culture represented by Confucianism, Buddhism and Taoism. They provided a guide for Chinese people to live in peace with others, with society and with nature, and gave birth to outstanding achievements in agriculture, medicine, astronomy and the study of calendars. Traditional Chinese culture, which values integrity, relevance, synthesis, tolerance and emotion, is different from the scientific culture of the West, which emphasizes rationality, criticism, analysis, experimentation and accuracy.

Scientific cultures established on different foundations are different, each with its own characteristics and strengths, requiring exchange and mutual learning. It must be recognized that China is still lagging behind in modern science compared with the advanced developed countries of the West. We should learn from them and carry forward the spirit of modern science. We should be modest and sincere, and willing to be students.

2. The features of different periods of Chinese and Western scientific cultures

At the beginning of modern science in the West, its primary purpose lay in advocating human rationality and exploring the laws governing the natural world. Utilitarianism was not its original intention. Today, the power of science is becoming increasingly evident. Thus, the desire to build a powerful country and deliver a life of prosperity has become an important force driving the advance of science and technology. However, an emphasis on the discovery of nature's secrets and the pursuit of pure knowledge and the 'use of useless knowledge' has always been an important element in the scientific culture of the West, a source of innovation and a powerful driving force for the development of science and technology.

When modern science was introduced into China, the nation was struggling for survival and the people were living in despair. The whole country was like a person in a deep sleep who might never wake up. Faced with this situation, Chinese intellectuals were extremely depressed and anxious, so they turned their eyes to the world in search of solutions that could save their nation, develop their country and improve the lives of their people. Modern science provided a glimmer of hope for these patriots. They studied and applied Western science and technology in China. They were not just willing to devote themselves to the pursuit of pure knowledge of the natural world, but were also committed to ending their national humiliation by realizing national prosperity and the people's happiness. To them, science was a powerful weapon and a tool for saving and serving the country. Instead of merely talking the talk, they were involved in practical actions.

In this sense, the pursuit of national survival and prosperity was the main characteristic of the scientific culture in modern history of China. It was during the process of accepting, spreading and promoting scientific culture that Chinese intellectuals developed the rational spirit and the ideas of democracy and freedom that separated them from the traditional Chinese intelligentsia, and shaped their deep collective feelings, national consciousness and patriotic spirit. This unique scientific culture has been passed on to this day, and blended into the blood of generations of Chinese scientists.

3. The regional features of the scientific culture of China today

Owing to China's vast territory, its regional differences in geographical environments and culture, and imbalances in economic and social development, the scientific culture of the public, including its knowledge, interests, attitudes, participation and understanding of the relationship between science and society, varies from region to region.

The results of the recently published survey of the scientific literacy of the Chinese people in 2018 show that the proportion of citizens with basic scientific literacy in both Beijing and Shanghai has exceeded 20%. However, apart from Tianjin, Jiangsu, Zhejiang and Guangdong, no other province, municipality or autonomous region has reached 10%. Nineteen provinces, municipalities or autonomous regions even fall below 5.5%, with the lowest at only 1.93%. The regional differences are more than evident.

One phenomenon revealed by the survey is that, in provinces with relatively high levels of economic development, the overall level of scientific literacy is relatively high, and some citizens with high levels of scientific knowledge have already developed a critical scientific spirit and started to reflect on issues such as the limits and ethics of science. In provinces with relatively low levels of economic development, people with low levels of scientific knowledge tend to be blindly optimistic about the social impact of scientific and technological progress. In addition, the correlation between the level of scientific knowledge and the level of interest and attitude toward science also varies from region to region.

Modern science has been introduced into China for more than 100 years, and it has taken root, blossomed and yielded bumper fruits. The fact that the scientific culture of modern China has different features in different regions and communities not only reflects unbalanced regional development in China, but also shows that the scientific culture of modern China has entered a new stage that requires reflection, upgrading and cultivation.

4. The mainstreams of the Chinese and Western scientific cultures

Scientific culture is an important part of the economic and social system, which inevitably takes on different features at different stages of economic and social development. This means that, during these different stages, efforts to develop scientific culture and science and technology should have different focuses and emphases.

In the process of Western industrialization, the positive role of science and technology was widely recognized. Most people held a positive view towards accelerating the development and application of science and technology. Scientific culture thus became a mainstream value in society. During the post-industrialization stage, the problems associated with the development and application of modern science and technology triggered people's reflections and criticisms. The rise of disruptive technologies, such as in the life sciences, information technology and artificial intelligence, also caused concerns about dysfunctional scientific research and the disorderly application of science and technology that could ultimately hurt humans themselves. These events also make diversity a more prominent feature of scientific culture in the post-modern era.

China is still the largest developing country in the world, and is still in the primary stage of socialism. The proportion of Chinese citizens with basic scientific literacy is now 8.47%, 2.30% higher than the 2015 figure of 6.20%—a notable increase indeed. However, the proportion of United States citizens with basic scientific literacy reached 17% as early as 1999, and 28% by 2005; the figure for Sweden in the same year was a staggering 35%. All this points to a considerable gap between China and developed countries with regard to the basic scientific literacy of their citizens.

At the current stage, we should focus on promoting the scientific spirit and the development of scientific culture. We must always pay attention to the value of science and technology and keep this development on the right course. However, what is now more important is to emphasize the significance of scientific development, strengthen the popularization of science, vigorously promote the spirit of modern science, enhance the pace of scientific and technological innovation, and make science and technology a pillar for development and a guide to a bright future.

Distinguished guests, dear colleagues!

'Harmony in diversity' is the quintessence of Chinese culture. Scientific cultures are diversified by nature. Difference is no reason for conflict. It is different colours that make a magnificent painting, and different instruments that perform a pleasant melody. All things in nature coexist without hindering one another. All planets in the universe travel their own paths without collision. Minor virtues will converge into an ever-flowing river, and great virtues will benefit all others. It is this inclusiveness that creates a mighty world. As long as we embrace the spirit of inclusiveness, mutual understanding, mutual learning and sharing, we will be able to open up new prospects for the harmonious coexistence of the scientific cultures of all humans.

This is also the purpose of this conference.

Thank you!

Author biography

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Religious and traditional belief systems coexist and compete with science for cultural authority in West Africa

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Abstract

This study examines the coexistence of science with Christian, Islamic and African religious beliefs and its implications for science communication. Using Moscovici's social representations theory and focusing on his accommodation hypothesis, the paper draws from experiences in mental health care, vaccination controversies and viral epidemics using case studies from West Africa. It also draws similarities from historical vaccination controversies around the world and the Zika virus epidemic in Brazil.

The paper shows that Moscovici's accommodation hypothesis of cognitive polyphasia better explains the coexistence of science and religious belief, which can, however, be double-edged. It also shows that coexistence can lead to a positive cross-referral system, as in the case of mental health in Ghana; can have initial negative outcomes, as in vaccination campaigns in Nigeria and Cameroon; or can aid the spread and eventual containment of disease, as experienced during the Ebola virus disease epidemic in West Africa.

Thus, while science remains a reference beacon in all controversies, its coexistence with religious belief can lead to an initial plunge in authority from which it eventually recovers. The choice of authority is also complicated by the dual role of some scientists as religious leaders and by previous untoward experiences with science, conspiracy theories and rumours about Western interventions in Africa.

Key words

Cognitive polyphasia, cognitive dissonance, Christianity, Islam, African religion, science, representations, West Africa, cultural authority

1. Introduction

The truth in most of pre-colonial West Africa was informed by traditional belief systems, namely the gods, and enforced by practices and taboos. Divination through oracles, the word of the paramount ruler or a decision by a council of elders represented the truth. European colonial masters introduced Christianity, the scientific method and the Western

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legal system to West Africa. Islam arrived much earlier, along the trade routes from North Africa (ICG, 2010; Paden, 2005; Kenny, 1996).

During colonisation, both Abrahamic religions and the scientific method coexisted, while laws were enforced by the European legal systems. There were attempts by Islamic leaders in the north, over the decades, to replace traditional African beliefs; notable among those efforts was the Uthman Dan Fodio jihad, which envisaged a purification of Islam and the entrenchment of sharia law (see Anderson, 2002; Kenny, 1996). Christian missionaries and colonial authorities spread their faith through the erstwhile pagan south, while Islamic practices were left untouched in the north. Although Islam and Christianity were widely accepted in West Africa, traditional practices, such as *Ifa*, as a divination system, rather than being replaced, remained widespread in society and even spread from West Africa, and can now be found in the United States, Puerto Rico, Venezuela, Brazil and other parts of the world (Abimbola, 1994).

The post-colonial era presents a mixture of pre-colonial and colonial practices: Abrahamic religions; atheism; the scientific method; the English and French legal systems and their laws; taboos; and traditional African beliefs and practices of appeasing the gods (Odebode and Onadipe, 2011; Ellis, 2008; McCall, 2004; Anderson, 2002; Abimbola, 1994). Just as Islamic leaders and Christian missionaries sought to replace traditional religious practices, the scientific method now seeks to replace all belief systems. This is not solely an African phenomenon. It was envisaged by Jawaharlal Nehru in his quest for 'scientific temper', as outlined in his book titled *The Discovery of India* (Nehru, 1985[1946]). The notion of scientific temper, a pan-Indian debate, was to instil a spirit of scientific enquiry in Indian society (Mahanti, 2013) and establish the cultural authority of science over religion (Raza, 2018). The term depicts a clash of ideas, in principle, advocating religious belief as a hindrance to the spread of scientific ideas in society.

Research by the Pew Research Center (PRC, 2010) shows that, side by side with their high levels of commitment to Christianity and Islam, many people in Africa retain beliefs and rituals that are characteristic of traditional African religions. In four countries, over 50% believe that sacrifices to ancestors or spirits can protect them from harm. In 14 countries, more than 30% say they sometimes consult traditional healers. The research also notes that, while recourse to traditional healers may be motivated in part by economic reasons and an absence of health-care alternatives, it may also be rooted in belief in the efficacy of that approach.

The discovery of the Okija Shrine in Anambra State, south-east Nigeria, which was patronised by prominent politicians, Christians and other elite groups seeking divine intervention in various endeavours, exemplifies the continued existence of beliefs in the efficacy of African religious practices among social groups (Ellis, 2008). The popularity of the Bakassi Boys, a vigilante group noted for using charms to fish out criminals, and the rise of folk justice (Smith, 2004; McCall, 2004) may have evolved from the disenchantment of the public with the slow pace of the Western judicial system and the belief that supernatural interventions can be used to arrest criminals believed to have evaded justice using spiritual powers.

The World Value Survey Wave 6 (Inglehart et al., 2014) emphasises the importance of religion in Nigeria, and the data is similar for other African countries. Eighty-nine percent of Nigerians agree that when science and religion meet, religion is always right; the figure is 84% in South Africa. When asked to rate, on a 1 to 10 scale, 'How important is God in your life?', 64% of Nigerian respondents choose 10 and 90% choose 8 or above. What is interesting is that these beliefs are held by those well educated in the scientific method. In Nigeria, Pastor Enoch Adejare

Adeboye, a former university lecturer with a PhD in mathematics, heads the Redeemed Christian Church of God; Pastor William Kumuyi, a former university lecturer with a first-class degree in mathematics, heads Deeper Christian Life Ministry; and Pastor Daniel Adekoya, a former medical researcher with a PhD in molecular genetics, heads the Mountain of Fire and Miracles Ministries. These three churches have the largest congregations of Pentecostal Christians in Nigeria and branches all over the world. For these pastors, being a scientist does not lead to rejection of religion; both can coexist.

Equally interesting is that churches in many African countries also provide clinical medical services. Hospitals are run by religious missions such as the Catholic Mission, the Seventh-day Adventist Church, Pentecostal churches and other denominations. In addition, many churches in Nigeria have established universities where the scientific method is taught and practised. In Nigeria, the Redeemed Christian Church of God established the Redeemer's University; the Ajayi Crowther University was established by the Anglican Communion; Mountain Top University was established by the Mountain of Fire and Miracles Ministries; Bowen University was founded by the Nigerian Baptist Convention; and Anchor University was started by the Deeper Christian Life Ministry.

A study of trust in cultural authorities in Nigeria (Falade and Bauer, 2018) found high levels of trust in scientists and religious leaders compared to trust in the military, politicians, the judiciary, foreign non-government organizations (NGOs) and local NGOs. Factor analysis shows that whoever trusts a religious leader in Nigeria is also likely to trust a scientific expert. A study of PhDs in a South African university also shows that 43% of doctorates acknowledged faith in an omnipotent god, across all faculties (Falade, 2019a).

The scientific method is thus at the nexus of competing cultural authorities in West Africa. In crises, this authority is often challenged by Christian and Islamic religious beliefs and practices (hereafter referred to as 'modern' beliefs) as well as African religious rituals, traditions and practices (hereafter referred to as 'traditional' beliefs).

Bauer et al. (2019) propose two model images of how science works against a background of goodwill in society: the 'lighthouse' and 'bungee jump' models. The lighthouse model sees science as a beacon of light reaching into the sky and towering over the chaos (storm) beneath, attracting attention and pointing direction. The bungee jump model sees science as a high holding beam with an elastic line, going through a temporary and sudden decline in authority followed by a resurgence when it is not crushed on the rocks (crisis) below.

In the context of competing cultural authorities, and using the lighthouse and bungee jump models, this paper examines how the uptake of science communication in Africa is affected by modern and traditional beliefs and practices. The paper also examines the impact of previous experiences with science, rumours and conspiracy theories. It examines studies from Ghana, Nigeria, Cameroon, Liberia, Sierra Leone and Guinea and compares them with a Brazilian study and historical perspectives from Europe.

2. Theoretical perspectives

The two main theoretical perspectives in this arena are based on, on the one hand, the relationship between cultural authorities and common sense, and, on the other, the varying trust placed on science, religion and other authorities.

2.1 Cultural authorities and common sense

The problem with issues relating to science and society hinges on understanding common sense, which takes inspiration from many sources, including science, which has increasingly become a very important component (Bauer, 2009). Those sources, or cultural authorities, are the building blocks for the evolution of social knowledge as it moves between different social contexts and is appropriated by different social actors (Jovchelovitch, 2008). How those sources shape the uptake of scientific information is the focus of the book *Psychoanalysis: Its Image and its Public* (Moscovici, 2008; translated from *La psychoanalyse: son image et son public*, first published in 1962). The book examined the ways in which Freud's psychoanalysis permeated French culture in the 1950s, and its findings remain valid today for studies of the transformation of social knowledge by science.

Moscovici's three-prong paradigm proposes that when science meets common sense, it can be rejected, accommodated into existing systems of thought, or diffused into society and become accepted as a premise for behaviour. Moscovici's social representations paradigm, Joffe (2002, 2003) argues, is not about what is right or what is wrong but facilitates the understanding of social rationality and shared interpretive resources, which it reflects and cultivates. It also considers knowledge in relation to the local, social, cultural and historical contexts in which it is formed (Flick, 1998) and is useful in characterising the evolution of the content, structure and functions of the voices and images of public concern (Bauer and Gaskell, 1999). For Gaskell (2001), the paradigm assumes that social knowledge evolves within a dynamic public space of interaction, communication and debate.

2.1.1 Accommodation: Cognitive polyphasia and complementarity

Moscovici (2008) noted that a plurality of modes of thought can coexist within the same individual, and that this dynamism can be described as a state of *cognitive polyphasia* (Moscovici and Markova, 1998). The striking finding, according to Jovchelovitch (2008), is that, contrary to well-established interpretations of cognitive phenomena, the different forms do not appear in different groups or different contexts but are found to be capable of coexisting side by side in the same context, social group or individual. Furthermore, Falade and Bauer (2018) have shown that this relationship entails not merely the coexistence of parallel forms, but also complementarity, in which one way of knowing reinforces another.

2.1.2 Rejection and diffusion: Cognitive dissonance and hierarchy

For Moscovici, there can be diversity of opinions within the same social group or context, leading to, in addition to the accommodation hypothesis, the rejection of advice from scientific or other cultural authorities or its acceptance as superior knowledge and consequent adoption as a premise for behaviour (diffusion). Festinger's (1962) theory of cognitive dissonance provides an alternative two-prong paradigm of rejection or diffusion. For Festinger, the psychological discomfort inherent in cognitive dissonance will motivate an individual to try to reduce the discomfort and achieve consonance in favour of either the old or the new information. This is also the position of Luhmann (1986) on the transformation of social systems, as he argues that the communication of ideas may lead not to a consensus but to an open situation of rejection or acceptance. However, Falade and Bauer (2018) argue that this is not necessarily a choice between two forms, but can be a hierarchical relationship in which both coexist but one is rated higher in a particular context.

2.2 Trust in science, religion and other cultural authorities

Religion remains very important to the public in West Africa (Inglehart et al., 2014), and data shows that Nigerians have more trust in religious leaders and scientists than other cultural actors (Falade and Bauer, 2018). However, the same data also shows that the public bestows on both scientists and religious leaders similarly high levels of trust. This raises a dilemma in situations in which scientists and religious authorities have different opinions on the same issue, since, as Gaskell et al. (2010) argue, both are used as the basis of statements about the truth.

Some authors argue that the public's faith in science is similar to its faith in religion. 'Trust' and 'faith' (see Luhmann, 1998; Giddens, 2002, 2010) are used interchangeably here. For Durkheim (2001), faith in science was not necessarily different from religious faith, and Einstein (1940) believed that science could be created only by those who were thoroughly imbued with an aspiration for truth and understanding—a desire that he perceived to spring from religion. Einstein (1950) said that he could not conceive of a genuine scientist without a profound faith: 'science without religion is lame, religion without science is blind.' Einstein (1954), however, made clear that his religion did not include the notion of a god, which he described as a product of human weakness.

But can scientists, driven by a desire that originates from religion, believe in God? While Professor Francis Collins (2006), a geneticist, argued that this is the case in his book titled *The Language of God: A Scientist Presents Evidence for Belief*, Professor Richard Dawkins (2006), an evolutionary biologist, argued the opposite, that God almost certainly does not exist, in his book titled *The God Delusion*. Durkheim (2001) proposed a replacement model in which scientific representations replace non-scientific beliefs.

Science, according to Thomas Kuhn (as cited in Knight, 2004), is not some disinterested and isolated search for truth, free of metaphysics and manifestly a good thing in a naughty world. The history of science, he argues, is like the history of France, which is prone to revolutions, and each turn is associated with new beliefs about the world and with new language as the scientific community is converted to new ways of seeing and believing. Knight (1986) has also argued that, while it would be perverse to deny that there is progress in the sciences, there seems to be no way of knowing whether anything in present science will turn out to be true in the long run.

For Habermas (2003, 2006), post-secular society continues the work for religion that religion has done for myth, and secularisation is not a zero-sum game, since a democratic common sense remains osmotically open to both sides, without relinquishing its independence. Openness to both sides indicates coexistence or accommodation in what Moscovici (1984) described as cognitive polyphasia. Openness can also lead to rejection or acceptance of either form of knowing.

2.3 Methods and research objectives

Using Moscovici's accommodation hypothesis of cognitive polyphasia, this paper examines the coexistence of science and other cultural authorities in West Africa, in particular the roles of religions, customs and traditions in the uptake of science communication. The research approach is to review West African case studies that show how scientific advice is accommodated by other authorities in specific situations.

3. Case studies

Using the accommodation hypothesis, the following case studies examine the outbreak of the Ebola virus disease (EVD), which ravaged Liberia, Sierra Leone, Guinea and Nigeria, all in West Africa (Falade and Coultas, 2017). They also examine practices in mental health care in Ghana (Ae-Ngibise et al., 2010; Tabi et al., 2006; Gyasi et al., 2011); the tetanus toxoid (TT) controversy in Cameroon (Feldman-Savelsberg et al., 2000); the oral polio vaccine (OPV) controversy in Nigeria (Falade, 2015) and its occurrence in other countries and the Zika virus in Brazil (Falade, 2019b).

3.1 West Africa: Ebola virus disease

The EVD outbreak in West Africa exemplifies the role of science as a beacon of light (or hope) towering over a chaotic response to an invading species that has claimed more than 10,000 lives. It also shows the roles of non-scientific authorities in the uptake of scientific information (Falade and Coultas, 2017). Prior to the outbreak, the disease had been restricted to Central and East Africa. The only case in West Africa had been in Cote d'Ivoire in 1994, and the patient survived. Thus, the West African public had no previous experience of the disease.

3.1.1 Scientific perspectives

Ebola causes fever, vomiting, headache, muscle pain, diarrhoea, nausea, haemorrhagic fever and other symptoms and shuts down the immune system. To prevent the transmission of the disease, the public was told to avoid shaking hands, to wash hands frequently and to avoid 'bushmeat' such as bats and monkeys—the vectors. However, the symptoms were very similar to those of other known diseases, such as Lassa fever, dengue fever, malaria and cholera. Malaria also causes high fever and vomiting, while cholera causes vomiting and diarrhoea; both diseases are common in Africa.

3.1.2 Religious and traditional perspectives

At the beginning of the outbreak, pastors were laying their hands on the sick to cure them of 'spiritual attacks'. A leader told pastors that all those who fasted for 100 days should have no fear of Ebola but that they should avoid laying their hands on the sick. A Muslim opinion quoted the Quran: 'the Prophet said: There is no "Adwa" [transfer of a disease] by itself, but with the permission of Allah' (as cited in Falade and Coultas, 2017).

The traditional practices of sitting on mats to mourn the dead and washing their bodies by Bassonians, Kru and Grebo people brought the uninfected into contact with the virus. Many traditional secret societies also believed that a dead member's ghost would torment others if they failed to observe the traditional rite of passage of washing the body of the deceased. Both traditional and modern religious practices provided a steady stream of new hosts for the disease.

3.1.3 Accommodation: Collaboration between science and religion

Many churches ordered the suspension of the practice of shaking hands as a sign of peace and the serving of Holy Communion directly to the mouth. A religious leader in Liberia called on fellow men of God to stop laying their hands on the sick as a means of healing them and told imams to stop bathing the bodies of the dead:

> I beg you in the Name of Jesus . . . please stop laying hands on people in order to cure them of Ebola. To our venerable imams, I respectfully appeal to you in the name of Allah . . . please stop bathing dead bodies. (as cited in Falade and Coultas, 2017)

There were also calls for the suspension of traditional practices of mourning the dead.

The church was also a source of medical aid. Several religious institutions in Sierra

Leone, including the United Brethren in Christ Church Conference, received funds from abroad for medical equipment, and the Abundant Life Chapel Liberia Orphanage served as a home for children who had lost their parents to the disease.

3.2 Ghana: Mental health

The use of modern and traditional religious beliefs and practices for mental health care in Ghana is very widespread (Ae-Ngibise et al., 2010) and provides the first port of call for most people in rural areas who are constrained by their poor access to hospital treatment and by the cost of the treatment (Tabi et al., 2006). While their traditional religious healers use herbs and other spiritual methods to care for mental health patients, their modern religious healers believe in the efficacy of prayers to cast out the 'demons' suspected of being behind the ailment.

Ae-Ngibise et al. (2010) cited a government official who said 'healers have been part of our societies for a very long time and whether we like it or not, people with mental problems are going to go to them.' This statement was corroborated by a staff member of an NGO, who noted that 'the greater percentage of all cases of mental illness are addressed by healers' (Ae-Ngibise et al., 2010). Traditional and modern religious beliefs and Western clinical medical practices coexist in Ghana, as in most African countries (Anyinam, 1987; Ensink and Robertson, 1999; Puckree et al., 2002).

3.2.1 Public perceptions of mental health

In Africa, mental health problems are often believed to have spiritual origins. Ae-Ngibise et al. (2010) observed that many of the respondents they interviewed highlighted that traditional and faith healers were like clinical psychologists, providing counselling, in contrast to the curative approach of clinical medicine. Those views were also expressed in research by Tabi et al. (2006), in which one of the participants said that her experience of a family member being cured of epilepsy by a herbalist had led her to believe that there were diseases that required a spiritualist. Another participant in the same study said that the hospital approach was based on physical signs, while certain supernatural things were revealed to the herbalist to aid treatment.

3.2.2 Accommodation: Collaboration between science and religion

The health-care system supporting mental health in Ghana appears to have evolved into a collaboration between Western clinicians and traditional African and Western religious healers. These interactions consist of a 'cross-referral system' (Gyasi et al., 2011), which is, however, largely unofficial. Ae-Ngibise et al. (2010) quoted a nurse as saying they paid visits to mental health patients and encouraged the patients to also use hospital services. A pastor told the same authors that he normally referred his patients to the hospital first, before asking them to fast and pray. A Muslim healer also said that he referred patients to the hospital if he had tried all other possible methods and the ailment persisted. In addition, a health programme director reported the need for a relationship between clinicians and faith-based healers, since he had seen successful management in cases in which the church encouraged patients to take their drugs and kept managing them.

Tabi et al. (2006), however, argued that their findings suggested a complex system of competing authorities in the making of health-care choices by Ghanaians. Traditional and modern religious practices, Western clinical medicine, Western education, advice from family and friends and personal experience all coexist in both individuals and communities in Ghana, and combine to shape health-care choices.

3.3 Cameroon: Politics, religion and the tetanus toxoid vaccine

The TT controversy in Cameroon is a case study of how competing cultural authorities clash, characterising the bungee jump model of a fall into the abyss for science.

3.3.1 Public reaction to the tetanus toxoid vaccine

An anti-tetanus vaccination campaign was launched simultaneously with a major shift in state population policy (Feldman-Savelsberg et al., 2000), which involved the legalisation of contraception and a campaign promoting family planning. This occurred during a period of heightened political tension between the West and Northwest provinces, often referred to as the 'unruly Grassfields', and the central government. Opposition parties and democratic movements were also being formed in the months surrounding the launch of the anti-tetanus vaccination campaign. The campaign also occurred during a period of public disagreement between the pro-life Catholic group (the Family Life Association) and the central government over the safety of TT vaccine compulsorily administered to girls of childbearing age only by the government.

Rumours that the vaccine contained sterilising substances were interpreted by the opposition as revealing a deliberate attempt to reduce their population for electoral reasons, posing a threat to the Grassfields region's most culturally valued resource—human fertility. The tragic murder of a revered father who was a school administrator only reinforced rumours that the vaccine could make girls sterile (Feldman-Savelsberg et al., 2000).

In the early months of 1990, the controversy led to girls squeezing through doorways and leaping from the windows of their schools, fleeing the vaccination teams. The rumour soon spread to the Far North and East provinces, and the fear it created in public minds led to the immediate end of vaccinations in schools. The aftermath of the controversy was a sharp rise in teenage pregnancies and abortions as vaccinated girls sought to confirm their ability to bear children.

3.3.2 Sterilising vaccine: An international debate

The sterility campaign by the pro-life group against the TT vaccine continued worldwide. In 1995, an international pro-life organisation in the Philippines issued a statement declaring that the TT vaccine being administered to women of childbearing age in that country and in Mexico contained anti-human chorionic gonadotrophin (anti-hCG) hormones, which were capable of causing sterility in women (Miller, 1995).

The hormone hCG is necessary for the initiation of pregnancy and is produced in large amounts throughout pregnancy. There were indeed trials using anti-hCG vaccines partly funded by the World Health Organization (Jones et al., 1988; Jones, 1996) that involved two intramuscular injections and a promise of contraception effective for six months. The basic principle of a contraceptive (or antifertility) vaccine is to use the body's own immune defence mechanisms to provide protection against an unplanned pregnancy. The contraceptive, however, became a weapon for the pro-life campaigners and in their narrative was transformed from an 'antifertility vaccine' into a 'sterilising vaccine'.

3.4 Nigeria: Politics, religion and the oral polio vaccine

As part of the global effort to eradicate polio, national immunisation days were set aside in Nigeria by the federal government, commencing in the last quarter of 2000. This campaign was resisted from the onset by some religious leaders in northern Nigeria, who described the exercise as being against

Islamic injunctions; rumours of contamination with the AIDS virus were also widespread (Falade, 2015).

3.4.1 Public revolt

The crisis was aggravated in July 2003 when, in the midst of a nationwide campaign, two very influential Islamic groups—the Supreme Council for Shari'ah in Nigeria and the Kaduna State Council of Imams and Ulamas—declared that the vaccine contained antifertility substances and was part of a Western conspiracy to reduce the population of the developing world. The revolt peaked when some states in northern Nigeria, led by Kano State, banned the use of the OPV, citing its 'contamination by sterilising substances'. The Kano State Governor, Ibrahim Shekarau, described the ban as 'the lesser of two evils . . . to sacrifice two, three, four, five even ten children to polio than allow hundreds of thousands or possibly millions of girl children likely to be rendered infertile' (as cited in Falade, 2015).

Notably, many of the scientists supporting or opposing the vaccination exercise were from different disciplines (see Jasanoff, 1987), and some were also Islamic scholars. Among those opposed to the vaccination were a medical doctor, a pharmacist, a medical biochemist and a professor of science education. In favour were a professor of medicine and immunology, a professor of virology and a pathologist.

3.4.2 Religious perspectives

The West was seen as having a secret Muslim depopulation programme following wars in Bosnia, Afghanistan and Iraq, which appeared to be against Muslim countries. An Islamic cleric said, 'If they really love our children, why did they watch Bosnian children killed and 500,000 Iraqi children die of starvation and disease under an economic embargo?' (as cited in Falade, 2015). Also, in 1996 there was the infamous Pfizer Trovan drug trial in Kano State, during which some children died. Kano, the most populous state in northern Nigeria, was the first to ban the vaccine. An Islamic sect also declared immunisation to be un-Islamic.

3.4.3 Scientific perspectives

While the disagreement focused on safety, debate over the scientific risk of the vaccine was largely avoided. One in 200 infections would lead to irreversible paralysis. One in every 2.7 million first doses would lead to vaccine-associated paralytic poliomyelitis. Another problem is circulating vaccine-derived polioviruses when the vaccine changes genetically and the virus circulates in the population (which is rare). Immunodeficient vaccine-derived poliovirus also arises when some individuals become chronic long-term excretors of vaccine-derived polioviruses (CDC, 2012; WHO, 2012; GPEI, 2012; Minor, 2009; Modlin, 2010).

3.4.4 Accommodation: Collaboration between science and religion

Kano State eventually accepted the potency of the vaccine produced in Indonesia. Speaking about the acceptance, an Islamic preacher said, 'From what we were told at the meeting, the polio vaccine to infertility ratio had been exaggerated.' A Kano businessman, who was also at the meeting, said, 'Even though I do not understand most of the medical jargon of the committee, I am convinced the polio vaccination should go on.' The Kano State Governor, Ibrahim Shekarau, who had earlier banned the vaccine, later administered it to several babies. Also, following a five-day immunisation tour of Egypt in 2007, the Emir and spiritual leader of Gombe, Abubakar Alhaji Usman Shehu, admitted to journalists that, although he went on the trip as a 'doubting

Thomas', he had since been convinced of the vaccine's compatibility with Islam (Falade, 2015).

3.4.5 Vaccination: An international debate

McKinnon and Orthia (2017) compared the 19th and 21st centuries in Australia and found that government campaigns have not changed much and have been based on scientific facts, which are, however, likely to get lost in the plethora of information sources on the internet. For Leask, Willaby and Kaufman (2014), societal circumstances may contribute to a growing parental hesitancy. They include increasingly 'crowded' vaccination schedules; a lower prevalence of vaccine-preventable diseases; the hypervigilance of parents in relation to children and risk; and an increasingly consumerist orientation to health care (see also Pereira et al., 2013). The debate over the appropriateness of vaccination campaigns has been with us for centuries and has cut across continents (Table 1), and, given recent events in the United States (Song, 2013), may continue into the foreseeable future.

3.5 Brazil: Politics, religion and the Zika virus

The outbreak of Zika virus disease in Brazil, like the Ebola virus disease in West Africa also shows the devastating effect of an alien species and that public debates have both scientific and non-scientific perspectives. The focus here is the tension between politics, religion and science.

3.5.1 Scientific perspectives

Zika virus was discovered in 1947 in monkeys in Uganda but had no known adverse effect on humans in Africa. The disease then moved from Africa to Asia and, by 2015, had begun to spread in Brazil, in a population with no immunity. The *Aedes* mosquito species transmitting Zika in the Americas are *Aedes aegypti* and *Aedes albopictus*, which also transmit yellow fever, dengue fever and chikungunya. The symptoms of infection—fever, rash and joint pain—are similar. But, while the other diseases had previously been established in the Americas, Zika was unknown. Also, the previously known diseases do not affect the foetus, while infection by the Zika virus during pregnancy can cause infants to be born with microcephaly. In adults, there is an increased risk of neurological complications, including Guillain–Barré syndrome.

The *Aedes* mosquito is also found in Florida and Hawaii, and in hot weather in northern parts of the United States. It is also found in warm parts of Europe, including France, Portugal, Spain and Italy. Given its movement from Africa to Asia and the Americas, anxiety over its possible spread to the United States and Europe through returning travellers raised a global alarm at a time when the spread of EVD from Africa to the United States and Europe was still fresh in people's memories.

3.5.2 The church, politics and abortion

The Catholic Church is opposed to abortion and all forms of contraception, but those practices are among the options for protecting women against the disease. This reignited the debate over the church, the state and personal choice in Brazil. A cardinal in Brazil said that mothers must accept babies born with microcephaly 'as a mission', and that abortion was out of the question. In contrast, Pope Francis was more open to contraceptives, arguing that avoiding pregnancy was not like abortion, which he viewed as a crime and an absolute evil. Some Brazilians sought solace in God. One woman, when confronted with a diagnosis of possible microcephaly for her child, said, 'It's God's will: He wanted us to have a baby like this'.

Table 1: Challenges to the scientific authority of vaccines in history and across continents

Countries	Years	Communication themes / suspected effects	Opposing groups	Vaccine
United States	1721–1722	Transmits syphilis, plague, leprosy	Clergy and scientists	Smallpox
England	1840–1871	'Mark of the beast', against civil liberties, transmits syphilis	Working class, liberal reformers, church, scientists, etc.	Smallpox
United States	1890–1922	Medical tyranny, coercion, ungodly	Scientists, Antivaccination League, Christian Scientists	Smallpox
Brazil	1904	Torture code, vile secretions expelled from sick animals	Middle class, elite, church, press, congress members, etc.	Smallpox
United Kingdom	1974	Neurological complications	Scientists, public	DTP
Japan	1975	Neurological complications	Fallout of UK episode	DTP
United Kingdom	1998	Autism	Scientists, public	MMR
United States, Australia, New Zealand	1998	Autism	Fallout of UK episode	MMR
Cameroon	1990	Sterilising vaccine	Catholic priests and opposition politicians	TT
Tanzania	1990	Sterilising vaccine (anti-hCG)	Scientists, Islamic preachers	TT
Nigeria	2001–2009	Western conspiracy, contamination with HIV and antifertility substances	Islamic groups, politicians, scientists	OPV
United States	Post-2000	Asthma, diabetes, Guillain–Barré syndrome, encephalopathy, autism, inflammatory bowel disease, mercury exposure, intussusception, Gulf War illness	Scientists, public	DT, DTaP, DTP, hepatitis B, measles, MMR, OPV, rubella

Source: Falade (2014).

In the United States, one report noted that, while the feud on Capitol Hill over how to respond to the virus appeared to be a fight over how much money was needed, beneath the surface were issues that had long stirred partisan mistrust. They included Republicans' fears about the use of taxpayers' money for abortion and possible increased use of contraception, and Democrats' worries about protecting the environment from potentially dangerous pesticides (see Mooney, 2005).

4. Conclusion

Over the years, modern religious believers—Christian and Muslim—have sought to replace traditional beliefs. At the same time, scientists have sought to replace modern and traditional religious beliefs with scientific approaches. The diffusion model theorised by Durkheim has not been fully realised, as evidence suggests two additional options when society is faced with a new phenomenon:

rejection or accommodation. This agrees with Habermas's (2003, 2006) observation that post-secular society continues the work for religion that religion has done for myth, and that secularisation is not a zero-sum game, as a democratic common sense remains osmotically open to both sides.

The acceptance of science by religious authorities in Nigeria during the vaccination controversy and in West Africa during the Ebola crises has shown that Moscovici's accommodation hypothesis provides plausible explanations for the social phenomena prevalent in West Africa, where religion and science coexist and at times collaborate. Further evidence of collaboration is found in the treatment of mental health patients in Ghana, where there is cross-referral between modern and traditional healers and Western clinical practitioners. This phenomenon of cognitive polyphasia is also observed in the study of the Zika virus in Brazil and in the occurrence of controversies about vaccination worldwide. It affirms that scientific facts are not enough but are nested within other authorities.

This study has also shown that, while science remains at the centre of debates among cultural authorities, its position as 'superior' knowledge is often challenged by the religious, political and traditional spheres. Trust in science is not helped by rumours and conspiracy theories about the motives for scientific intervention, previous experience with Western powers and botched scientific experiments. The vaccination controversies in Nigeria and Cameroon show the effects of religious and political authorities on the uptake of scientific information, leading to a 'bungee jump' in scientific authority. However, while science may take a plunge, that is not a death knell, as it soon bounces back.

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The potential for anthropomorphism in communicating science: Inspiration from Japan

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Abstract

Anthropomorphism—the attribution of human characteristics to non-human animals or inanimate objects—is commonplace in many cultures around the world, but is particularly prominent and pervasive in Japan. Talking furniture on children's TV, vegetable mascots for city governments, an animated letter 'e' to promote online tax returns—there seems to be no limit to what can be anthropomorphized, and no corner of the culture where it is considered out of place. This of course includes efforts to communicate science, where we can find test tube narrators, angry viruses, friendly chemical elements, and a whole lot more. Scientists, on the other hand, are less enthusiastic about anthropomorphism in scientific discussions and tend to consider it to be inaccurate and unscientific. In science, thinking or communicating in anthropomorphic terms is generally derided. Where, then, does this leave the talking microbes and smiling proteins of Japanese science communication? While the literature has quite a lot to say about anthropomorphism, there is nothing specifically about its use for science communication. This paper draws on examples from Japan to consider the potential roles of anthropomorphism in the communication of science and related issues.

Key words

Anthropomorphism, science communication, visual communication, affect

Drawing inspiration from Japanese science communication and popular media, this paper reconsiders the potential roles of anthropomorphism—the attribution of human characters to non-human animals or even inanimate objects—in the communication of science. Certainly, Japan is not unique in its use of anthropomorphic characters, either for communicating science or for general communications. Anthropomorphism is common to many, if not all cultures around the world. However, it was the juxtaposition of Japanese popular culture with the author's Western scientific background that highlighted an apparent difference in perspectives and attitudes towards anthropomorphism, and led to the considerations in this paper. A different cultural perspective can sometimes prompt us to question our established ways of doing things and perhaps lead us to new approaches. The following discussion is an exploration of what might be learned from the Japanese example of the use of anthropomorphism in science communication.

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1. Anthropomorphism in Japanese culture

Japanese culture has embraced anthropomorphism with exceptional vigour. Anyone with even a passing interest in Japanese popular culture will have noticed how industrious the Japanese are at producing endearing characters. Even the most mundane objects are routinely transformed into walking, talking, thinking, feeling entities, and this is ubiquitous across every aspect of the culture, from ancient fables to modern manga. Anthropomorphism has a long history in Japan. Japanese ancient folklore is rife with a colourful array of human-like animals and spooky animated bogeymen. A well-known example of this is the *Chouju-jinbutsu-giga*, a culturally important set of picture scrolls dating from the 12th or 13th century, which are filled with frogs, rabbits, and monkeys wrestling, bathing, swimming, and participating in Buddhist ceremonies. Another clear example from folklore is the large group of mythical ghost-like monsters called the *Tsukumogami*, or 'Tool Gods'. *Tsukumogami* are all manner of ordinary household items, which after 100 years of service have acquired souls and become animated. They include troublemaking one-eyed straw sandals (*Bake-zori*), one-legged jumping umbrellas (*Hone-karakasa*), creepy paper lanterns with ghoulish faces (*Chochin-obake*), and much more sinister futons that strangle people in their sleep (*Boroboroton*). Some scholars of Japanese culture point to Japanese spiritual foundations—the animism of Shintoism, which proclaims that all things have a soul or spirit, and Buddhism, which does not distinguish between the animate and inanimate—and suggest that these influences created an environment in Japanese culture that enables an easy acceptance of anthropomorphism even today (Asquith, 1981; Occhi, 2012).

Of course, anthropomorphism is not constrained to the past, and contemporary children's media are packed with talking animals and other objects. Although this is the case in many other countries as well (for example, the USA's Disney and Sesame Street, the UK's Thomas the Tank Engine), there seems to be a broader potential for what can be anthropomorphized into characters for Japanese children's television shows, cartoons, and picture books. One popular Japanese television show includes such characters as singing shoes, a chuckling maracas fairy, dancing potatoes, a flying toothbrush, and even a toilet king, while another features the capers of a whole village of talking chairs.[1] These are by no means exceptional examples, but rather quite typical.

However, anthropomorphized characters are not restricted to children's stories. They appear in all manner of roles right across Japanese society. Many companies have their own mascot character, which in simple cases may be modelled on an animal (for example *Jetta*, the charismatic red panda for economy airline Jetstar[2]), or in other cases on an entirely inanimate object, such as *Domo-kun*, the friendly television-shaped monster of national broadcaster NHK. Many prefectures and municipalities also have mascot characters to promote local products or characteristics of the region. These characters are often called *Yurukyara*, a term that connotes affection for their endearing goofiness. *Yurukyara* range from historical figures,[3] animals, fruit and agricultural products[4] to more unlikely candidates, such as geographical features[5] or even fruit–animal combinations.[6] *Yurukyara* are extremely popular with the public and number in the thousands. They regularly appear on TV news, variety shows, and other media and compete in an annual '*Yurukyara* Grand Prix' event to decide the most (and least) popular characters. In addition to promoting companies and regional specialties, anthropomorphic characters are also employed for public relations by government departments[7] and are common in government public education campaigns.[8] In addition, there are countless unsung anthropomorphized characters scattered throughout advertising and promotions, events and festivals, tourist maps, instructional and guidance materials, children's textbooks, souvenir shops, warning signs, and more.

All this illustrates that anthropomorphism is a significant feature of historical Japanese culture and is ubiquitous in the current sociocultural landscape. Given the pervasiveness of anthropomorphism in Japanese culture and communication, one might speculate that individuals raised in this environment would be comfortable with and accepting of anthropomorphized characters, even those that may be more jarring for people from other cultures. Walking, talking characters based on animals, furniture, mountains, or even abstract concepts such as human rights are not seen as implausible, or even as curiosities, but as a given—a natural part of the cultural environment.

2. Anthropomorphism in Japanese science communication

Since this culture of anthropomorphism pervades every aspect of Japanese society, it should not be surprising that it is also common in science education and science communication. Here, I will focus on examples of visual or illustrated instances of anthropomorphism, rather than anthropomorphic terms or suggestions of human-like behaviour in narratives and text. This is because visual examples are more readily identifiable and because I feel that it is the use of visual anthropomorphism that to some extent separates Japanese science communication from that of other countries. Examples of anthropomorphized characters and narrators are not uncommon among Western science communication materials aimed at children.[9] However, in Japan, while anthropomorphized science is more common in materials for younger children, it also appears in explanations of science topics for adults, for example in health communications[10] and informational television shows.[11] Furthermore, Japanese examples are likely to anthropomorphize not only narrators or explainers but also entities that form part of the explanation itself. For example, an explanation of influenza transmission may include anthropomorphized virus particles, represented with evil, grinning faces and pitchforks, gleefully attacking their victims. Or diabetes might be explained using anthropomorphized sugar and insulin molecules, illustrated as rudimentary shapes with arms, legs, and faces, moving around the body and struggling to cope under poor health conditions. The emphasis here appears to be on conveying a broadscale awareness of the cause and mechanism of disease rather than a detailed understanding. This approach of integrated anthropomorphism is also quite common in children's science texts and supplementary learning materials,[12] in which explanations of cloud formation, air pressure, and chemical reactions feature air molecules, water vapour, Bunsen burners, and test tubes, all with smiling faces and an apparent life of their own. Even the periodic table of the elements has been entirely anthropomorphized (several times) with each element adopting an individual persona.[13]

Comics are also a rich part of Japanese pop culture. The Japanese are adept at using the comic format to turn even the most humdrum topic into an interesting adventure. Constructing a comic requires the development of characters and a narrative, and that process provides ample opportunity for anthropomorphism. It seems that almost every subject area imaginable has been transformed into comic format at some point in Japan, and of course science topics are no exception. Some recent examples, noteworthy both for their popularity and the extent of their anthropomorphism, are *Moyashimon—Tales of Agriculture*,[14] and *Cells at Work* (*Hataraku Saibou*).[15] *Moyashimon* is the story of an agricultural university student who can see and talk to micro-organisms. Through his activities and misadventures at school, the comic introduces a range of micro-organisms and their roles in medicine, disease, and fermented food production. The anthropomorphized micro-organism characters are shaped to vaguely resemble the species that they represent, but with the addition of arms, legs, and faces and the ability to talk and express emotions. *Cells at Work* portrays a range of human body cells (such as red blood cells, white blood cells, platelets, and immune system cells) as youthful employees, and through their actions explains the functions of those cells in maintaining the body and in response to injury and disease. While the antagonists in this story (for example, disease-causing viruses and bacteria) are sometimes alien-like in form, the protagonist body cells are represented in an entirely human form. There is nothing about their physical appearance to suggest they represent cells, and, at a cursory glance, one would not see this comic as anything but a story involving human characters. The characters of course talk to each other, but also cooperate, fight, suffer, rejoice, bleed, and cry. It is interesting to note that, although *Moyashimon* and *Cells at Work* contain what might be deemed educational content, they are not necessarily motivated by educational or science communication goals, but rather are highly successful commercial projects. It is impossible to determine the extent to which anthropomorphism has contributed to the success of these comics, since that factor cannot be considered separately from the plot, narrative, illustration style, and many other elements that make up a comic, but it would seem that anthropomorphism, even to the extent that it appears in these publications, certainly does not detract from their popularity.

Anthropomorphized comics have also been used for genuine science communication projects with educational goals. *Nymphs of the Plant Hormones* (*Shokubutsu Horumon Gijinka*)[16] is a project aimed at raising awareness and understanding of plant hormones. A range of hormones are personified as female high school students, complete with profiles, nicknames, and key features, and through those characters and their interactions the comic introduces the functions and characteristics of various plant hormones. As in *Cells at Work*, these characters are human (rather than merely having human-like attributes) and portray the characteristics of hormones through their names, personalities, and behaviour rather than their physical appearances. *Higgstan*[17] is a series of four-frame comics that explain concepts and research endeavours in particle physics. The main characters of the comics are child-like characters that represent research institutes, such as the Japan Proton Accelerator Research Complex and the Super-Kamiokande neutrino detector. Those characters act as explainers, but the explanations also feature anthropomorphized electrons, atomic particles, quarks, dark matter, gamma rays, and more, which are generally illustrated as basic shapes with faces, sometimes with hats or sunglasses, or holding signs.

While anthropomorphized science instruction and science communication also exist in other cultures,[18] from personal observation and a Western perspective, anthropomorphism in Japanese science communication is conspicuous for its prevalence, diversity, and widespread acceptance (as it is in all areas of the culture). In many cases, this anthropomorphism would be likely to raise eyebrows among Western scientists and science communicators. However, the commonplace nature of anthropomorphized explanations of science suggests that this is popular with audiences in Japan, or at least is perceived by authors as popular or easy to understand.

3. Anthropomorphism from a (Western) science and science education perspective

Despite this enthusiastic anthropomorphization of scientific explanations in Japan, the world of science has traditionally taken a different view. In science, anthropomorphism is bad, and that has long been the dominant position. The argument is that atoms, molecules, cells, and so on do not 'feel' or 'want' anything—their behaviour is driven by causative relationships rather than human-like motivations. Therefore, thinking in anthropomorphic terms is simply not scientifically accurate and might lead to flawed conceptualizations of the true nature of phenomena. It may seem that considering chemical bonding in terms of atoms 'wanting' an additional electron is just a harmless figure of speech, and in many cases it probably is, but some scientists worry that this has the potential to influence the direction of scientific research *per se*. For example, in a criticism of widespread anthropomorphic thinking in the field of microbiology and a warning of the dangers to scientific progress, Davies (2010) described how teleological thinking associated with anthropomorphism restricted science's understanding of antibiotics. He claimed that descriptions of antibiotics having 'militaristic' functions in a 'war' against invaders impeded or discouraged alternative conceptions of other possible functions of those molecules, and consequently delayed the current awareness that antibiotics may have a range of roles in transcription modulation, regulating, and signalling. The fundamental error in interpreting natural processes and relationships in terms of human motivations is evident for physics and chemistry, as well as areas of molecular biology as described above. However, in other areas of biology, particularly animal behaviour studies, there is an ongoing debate over whether it is necessarily incorrect to interpret higher order actions of non-human animals in terms of the emotions, desires, fears, and so on that we would ascribe to human behaviours (Wemelsfelder et al., 2001; Wynne, 2004; Watanabe, 2007). For the sake of managing the complexity of this discussion, however, I will restrict the scope of consideration here to processes and phenomena that are more objectively devoid of human-like motivations.

Since anthropomorphism is unscientific, it has also been considered unsuitable for science training and education. For decades, anthropomorphic analogies in science education have been thought to be an impediment to learning, primarily through their association with teleological explanations for the causes of phenomena, which involve desires and human motivations (Dorion, 2011), the likes of which are described at the beginning of this section. Intuitive anthropomorphic reasoning has been seen as characteristic of the early stages of childhood development (Dorion, 2011) and therefore as a childish means of explanation. This has led to widespread normative appeals to eliminate anthropomorphic explanations from science education and a traditional stance of avoiding the promotion of anthropomorphism (Dorion, 2011). However, although this has been the predominant view for some time, it has not been unanimous, and several authors have suggested that anthropomorphic explanations may have useful roles to play in science education. For example, Watts and Bentley (1993) pointed out that anthropomorphic thinking is common in the causal explanations of both children and adults. They argued that this is not something that children simply grow out of, but rather should be approached as a starting point for building correct ways of thinking, in the same way that other kinds of misconceptions are acknowledged and countered in a constructivist classroom. Taber and Watts (1996) recommended acknowledging the widespread use of anthropomorphic language among both students and scientists, arguing that some of that language is not problematic, since it is understood to be a convenient means of explanation or communication and not to be taken literally. They went on to offer an approach to classify such language into that which is useful for communication and understanding, and that which may mask misconceptions. Pinchas and Anat (1991) claimed that anthropomorphic and teleological explanations have useful heuristic value for students. Explanations in terms of purposes and intentions that align with what we know about our own behaviour are more intuitive and help students to 'organize facts and better understand natural phenomena and processes'. Dorion (2011) continued in this direction to explain that anthropomorphic explanations, which are already common among science students, may play a variety of roles in the development of students' understanding of scientific concepts by allowing them to work with and build on as yet incomplete conceptualizations of learning goals. He went on to suggest that working with anthropomorphism may offer teachers an opportunity to bolster a tactic that students already use to develop their understanding. Zohar and Ginossar (1998) also proposed an end to the 'taboo' on teleology and anthropomorphism in biology, citing the lack of a correlation with students' development of anthropomorphic or teleological reasoning (despite widespread exposure to such depictions), along with the apparent heuristic advantages.

A growing number of such voices coincide with a recent apparent softening on anthropomorphism in science education. The American Association for the Advancement of Science publishes *Benchmarks for science literacy* (AAAS, 2009) which serve as a guideline for school science education in the United States. The 1993 benchmarks recommended that by second grade children should be made aware that 'stories sometimes give plants and animals attributes they really do not have.' However, this has been deleted from the most recent benchmarks published in 2009. Instead, the current version states that, while 'the anthropomorphism embedded in most animal stories causes some worry', developing an interest in reading is more important than 'rigidly correct impressions'. The benchmarks suggest that anthropomorphism can be ignored in the classroom, or students can be guided towards noticing differences in how animals are portrayed (realistically or anthropomorphized) in different books.

In sum, science considers anthropomorphic and teleological thinking to be inaccurate and potentially harmful to the progress of science. Although science education traditionally shuns anthropomorphism for those same reasons, there has been some debate over whether this is the most appropriate approach to handling anthropomorphism in the science classroom.

4. Potential influences of anthropomorphism

Although science communication often plays an educational role, it is also often concerned with attitude and behaviour change, and is thus a different animal from science education. Science has a clear stance on anthropomorphism, while the science education community has debated and continues to debate its own position. It is interesting, then, that the impacts of anthropomorphism specifically on the public communication of science appear to have been largely overlooked in the literature. There is no clear stance on anthropomorphism from the field of science communication, nor discussion on its potential roles and risks. However, there are some reports from cognitive psychology and science education that provide hints of what those impacts might be.

To understand why people anthropomorphize, Epley et al. (2008) examined and provided evidence for two motivational factors, which they named *effectance motivation* and *sociality motivation*.

Effectance motivation is rooted in the idea that the human tendency to anthropomorphize agents is an example of induction, or the process of reasoning about an unknown or unfamiliar entity based on what is known about a more familiar, related entity. In other words, anthropomorphism can be seen as a process of applying a familiar 'human' framework to interpret an unfamiliar concept. This is essentially the heuristic value for students proposed by several authors and discussed in the previous section. People employ anthropomorphism as one means of gaining a sense of efficacy and satisfying a basic psychological need for an understandable, predictable environment. Epley et al. (2008) were able to show that people with a strong need for this sense of efficacy and understanding were more likely to view an animal in anthropomorphic terms when they had less understanding of the animal's behaviour (the animal's behaviour was less predictable). It seems that when presented with a knowledge gap, motivated individuals might employ an anthropomorphic explanation to help them close that gap. It is reasonable to suggest, then, that when grappling with an unfamiliar scientific concept, the more familiar framework of an anthropomorphized explanation might offer a more readily understandable explanation, which at least some individuals will be tempted to accept. For example, an anthropomorphic explanation for why trees produce fruit (for example, to entice birds to disperse the trees' seeds) may facilitate a digestible and acceptable, albeit scientifically imprecise, understanding. In fact, there is some support for this in the literature. For example, Stoos and Haftel (2017) found that students involved in structured anthropomorphic storytelling as part of a microbiology course performed better on exams than students in a regular class. Marketing research has also shown that a highly anthropomorphized portrayal of an influenza drug fighting influenza virus led viewers to a stronger perception that they understood how the drug worked (actual comprehension was not assessed). This in turn led to an enhanced perception of the drug's efficacy (Laksmidewi et al., 2017).

In science communication settings, then, a story of an 'angry' virus invading a 'hapless' cell to 'wilfully' inflict damage and chaos, followed by the counter-attack and triumph of the body's 'brave and noble' defences may set up an immediately accessible and understandable framework for explaining influenza infection and immune response, compared to a more scientifically acceptable explanation of random encounters and a complex chain of chemically triggered reactions. In this case, the decision of whether or not to use anthropomorphized characters would depend on the objectives of the communication and the relative necessity of detailed and precise scientific understanding. Of course this must also be weighed against the risk of harmful misunderstandings and misinterpretations originating from teleological explanations.

Sociality motivation, the second motivational factor described by Epley et al. (2008), stems from the need to be socially connected. Being social animals, humans have a psychological need to connect with other humans. This need is so strong that, in the absence of other human contact, individuals will construct a proxy in the form of anthropomorphized animals or objects. Epley et al. (2008) demonstrated this by revealing a higher tendency to anthropomorphize pets among individuals with a strong need for social connection (that is, with fewer human social contacts). It might also be expected that these individuals are not only more likely to anthropomorphize their surroundings, but also to respond differently when they are presented with anthropomorphic depictions. Tam (2015) demonstrated precisely this when he found that anthropomorphism in conservation messages led to a greater influence on conservation behaviour among people with a strong need for social connection. That study was interesting not only for identifying that certain groups respond more predictably to anthropomorphism, but also for demonstrating that anthropomorphism can contribute to communication objectives (in this case behaviour change) through its influence on affect or attitudes.

Other apparent influences of anthropomorphism on attitudes and non-cognitive factors are also described in the literature. Chartrand, Fitzsimons and Fitzsimons (2008) noted previous research demonstrating that the perceived attributes or expectations of people around us can lead to behavioural change and considered whether anthropomorphic images might also command such influence. They found that showing people pictures of animals primed them with stereotypical anthropomorphic characteristics of those animals. This then led to unconscious changes in behaviour intentions that conformed with the stereotypes. Specifically, people primed with images or thoughts of dogs indicated elevated intentions of loyal behaviour (an attribute typically associated with dogs in the sample group) in a subsequent unrelated task. Those primed with cats (typically considered not to be loyal) indicated decreased intentions of loyalty. This study demonstrated that attitudes associated with an anthropomorphized character may be transferred to the object being anthropomorphized. Similarly, in a study investigating viewers' interpretation of anthropomorphized software interfaces, realistic human representations of the interface agent (compared with 2D representations and stylized caricatures) were interpreted as more capable and intelligent (King and Ohya, 1996). This suggests that not only attitudes but also a viewer's assumptions or expectations associated with an anthropomorphic representation are applied to the anthropomorphized object itself. It is not difficult to imagine how these types of effects might be important in the communication of science topics. Consider, for example, a health communication message aimed at encouraging people to take steps to avoid influenza infection. If this message portrays a virus particle as a grinning, evil-looking antagonist, and that stimulates a sense of fear or apprehension towards viruses, this might be more likely to bring about the behaviour change that the message is aiming for, and justify the reduction in strict scientific accuracy.

Some recent studies on the affective impacts of visual design in science instructional materials explore how 'emotional design'—the manipulation of the visual design of educational resources to trigger affective responses—can influence motivation and learning outcomes (Mayer, 2014). Anthropomorphism is one aspect of emotional design, and researchers found that, in a multimedia explanation of the immune system, depicting antigens and immune system cells with faces led to increased positive emotions, comprehension, and ability to apply the learning goals to new situations (Um et al., 2012; Plass et al., 2014). The suggestion here is that the anthropomorphic design has a positive influence on viewers' emotional state, leading to improved comprehension and transfer via elevated motivation.

This section draws from diverse segments of the literature, but together they suggest that anthropomorphism can offer a familiar framework for dealing with new or challenging topics, as well as affective and attitudinal influences that may be important for motivating comprehension and for encouraging attitude and behaviour change.

5. Conclusions and recommendations

What can we conclude about the use of anthropomorphism in science communication? On the one hand, describing phenomena in anthropomorphic terms is not scientifically precise, and there are valid reasons for concern about anthropomorphism in scientific contexts. However, some areas of the literature suggest that anthropomorphism might not necessarily lead to erroneous conceptions and teleological reasoning, as predicted by the traditional view—the perceived threats to accurate learning that are the basis for shunning anthropomorphism in science education. Rather, anthropomorphic frameworks may offer a familiar and approachable format for more understandable explanations of often complex and unfamiliar science. These anthropomorphic heuristics might help students eventually develop accurate understandings and offer additional tools for engaging learners. Science communicators must consider, then, what degree of detailed scientific precision is required for a particular communication, how much priority is to be placed on ease of understanding and approachability, and the audience's 'anthropomorphic literacy' or the extent to which they understand the metaphorical function of anthropomorphism. For example, when encouraging an audience to take basic steps to avoid influenza transmission, is the scientific imprecision of a virus's evil grin outweighed by the familiar and understandable metaphor for danger and anomaly? Do the highly figurative portrayals of something like *Cells at Work* present broad themes of cell biology in an immediately recognizable and memorable way that justifies the sacrifice of specific details and the risk of teleological misunderstandings? Perhaps. Therefore, it is important that we carefully consider the value of anthropomorphism for the specific objectives of science communication.

In addition to conveying accurate information, science communication efforts are often concerned with emotional, attitudinal, and behavioural outcomes, and anthropomorphism has been shown to influence each of these. The literature describes how anthropomorphism can induce positive emotions, influence value judgements and attitudes, and subsequently impact on behaviour. With this in mind, take a frivolous example of an explainer in a science communication context portrayed as a friendly anthropomorphic magnifying glass. Despite the superficial absurdity of the character, could it have important impacts on viewers' interest and motivation, or even induce behaviours such as scrutiny and attention to detail that may be stereotypically associated with magnifying glasses? This is a deliberately provocative example, but it demonstrates how it would be useful to understand these interactions in more detail.

Responses to anthropomorphism are likely to vary. At a minimum, we would expect differences between individuals according to their psychological need for efficacy and social interaction, but there are likely to be a range of other contributing variables as well. We might also expect broader trends between cultures with different general levels of acceptance and adoption of anthropomorphism. For example, an individual raised in the anthropomorphically rich culture of Japan would be expected to have different acceptance, interpretations and understandings of anthropomorphized science than a counterpart from another country, so there is unlikely to be a one-size-fits-all approach that is the best option in all situations. Rather, the impacts of anthropomorphism in science communication are likely to be highly nuanced, and universal norms or recommendations may not be possible. Despite this, there seems to be a broad range of potential impacts of anthropomorphism in science communication settings. Some of them may be useful, but of course they must be reconciled with the need for scientific accuracy, and the decision of whether or not to anthropomorphize will ultimately be determined by the goals and constraints of a particular setting. Unfortunately, we currently have a very limited understanding of what those impacts might be and how they might contribute to science communication goals.

Fortunately, in Japan, there exists a rich variety of anthropomorphic science communications from which there may be much to learn. It is not clear whether Japanese science communicators have embraced anthropomorphism in a conscious effort to employ the potential impacts discussed here. However, they clearly do not appear to be concerned about potential negative impacts. Unfortunately, there are few means to determine the success of their approach. The commonplace nature of anthropomorphism in science communication suggests that there is a perception that this is a useful tool. However, there appears to be little in the way of evaluation. Scholars of literature and cultural studies have appraised *Moyashimon* and *Cells at Work* for their educational value (both scientific and sociopolitical) (see Berndt, 2017; Greene, 2018). However, there are no data assessing the influence that these and other such publications have had on readers' understanding and awareness of or interest in the scientific topics described within them; nor is there any estimate of the degree of misconceptions they may have spawned. There is certainly no measure of the independent impact of the anthropomorphism that they contain. However, it is highly likely that the comics, along with their anthropomorphism, have had some kind of influence, both at the level of an individual fan and, given their widespread popularity, at the population level as well. In the absence of any other measure of the impact of anthropomorphism, it is tempting to look at population-wide standardized tests of science literacy. Japan typically does very well on the PISA (Programme for International Student Assessment) international competency test, consistently ranking in the top three for science among countries in the Organisation for Economic Co-operation and Development (Tasaki, 2017). However, it would be preposterous to attempt to attribute this to the use of anthropomorphic science explanations. At best, it is an indication that, within the overall context of a Japanese student's education, the presence of anthropomorphism in science explanations does not seem to have a significant negative impact (in so far as the PISA test is a true measure of science comprehension). Furthermore, this is only a consideration of comprehension and disregards other important objectives of science communication, such as attitude and behaviour change.

What are needed are controlled empirical assessments of the influence of anthropomorphized characters in descriptions of science content on comprehension, interest, attitude and affect. This is an area in need of further research and with the potential for highly rewarding and useful outcomes. Certainly, in light of what is happening in Japan, it would seem prudent to gain a better understanding of the influence of anthropomorphism and how it might be useful for the specific purposes of science communication before summarily dismissing it as childish nonsense.

Notes

1. National broadcaster NHK's *Inai Inai Baa* and *Miitsuketa*. See http://www.nhk.or.jp/kids/.
2. Another interesting example is the telecommunications company Softbank's talking dog, which is also inexplicably the father of an otherwise human household.
3. For example, the Ibaraki Prefectural Government's *Hustle Komon* is inspired by a TV dramatization of the exploits of famous *daimyo*, Tokugawa Mitsukuni.
4. For example, *Sashibanosa-chan*, the hawk mascot of Ichikai Town, or Akaiwa City's peach and grape character, *Akaiwamomo-chan*.
5. For example, Sapporo City Western District's *Sankakuyamabe*—a walking green triangular mountain.
6. For example, the strawberry and deer mash-up, *Yumezukin-chan*, of the Nagasaki branch of Japan Agricultural Coop.
7. For example, the Tokyo Metropolitan Police Department's *Pipo-kun,* and the Ministry of Justice's human rights mascot *Jinken Mamoru-kun.*
8. For example, *Maina-chan* for the government's personal identification scheme (My Number), and *Saiban-inko* for the introduction of a new jury-based legal system.
9. For example, Professor Jay Hosler's comics explaining *Apis* ecology, photosynthesis, and more use anthropomorphized bees, ants, and other insects as explainers and explainees. See https://jayhosler.com/science-comics.html.
10. For example, simple anthropomorphic figures representing insulin and glucose in an explanation of diabetes used by the Citizen – Medical Staff Alliance for the Prevention of Lifestyle-related Diseases. See http://www.kozonokai.org/medical-inf/tounyou/what.
11. For example, the popular TV health programme *Tameshite Gatten* regularly uses graphics and elaborate models containing anthropomorphized elements. See http://www9.nhk.or.jp/gatten.

[12] For example, *Visual Science Encyclopaedia* (ビジュアル理科事典, published by Gakken Plus in 2015), *Learn Middle School Science the Clever Way—4 Frame Classroom* (中学理科がちゃつかり学べる ゆる4コマ教室, published by Gakken Plus in 2018).

[13] For example, *Wonderful Life with the Elements* (元素生活, published by Kagakudojin in 2015), *Element Girls* (元素周期 萌えて覚える化学の基本, published by PHP Institute in 2008), and *Learn the Periodic Table with Comics* (マンガで覚える元素周期, published by Seibundo Shinkosha in 2012).

[14] *Moyashimon–Tales of Agriculture*. See http://kamosuzo2.tv.

[15] *Cells at Work (Hataraku Saibou)*. See https://hataraku-saibou.com.

[16] *Nymphs of the Plant Hormones* (*Shokubutsu Horumon Gijinka*). See http://hormone.webcrow.jp.

[17] *Higgstan* comics can be seen at http://higgstan.com.

[18] For example, the Swedish/US company Toca Boca produces chemistry and plant biology apps for children that heavily feature anthropomorphized chemical elements and plants (see https://tocaboca.com/apps/), while Dan Green and Simon Basher have published a series of science books featuring anthropomorphized organs, cells, chemical molecules, and even qualities such as mass and weight.

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Comparing public attitudes towards science across provinces in China[1]

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Abstract

To illustrate the feature and structure of cultural authority of science in a Chinese context, this study reports on the features and current status of the cultural authority of science across China via a structural analysis of public perceptions of science as measured by cognitive, evaluative and behavioural indicators. Regional socio-economic disparity in China is significant, and we expect that disparity to give rise to diverse public attitudes to science. This study aims not only to enrich the regional data on current international efforts to compare public attitudes to science, but also to provide evidence-based research for other countries to discuss the diversity in the patterns of the cultural authority of science.

Key words

Public attitudes to science, scientific literacy surveys, cultural authority of science

Since the founding of the People's Republic of China, China's science and technology (S&T) development has been carried out under a government-led strategy. With the recent new focus on an 'innovation-driven development strategy' as China's basic policy in the 'New Era' of China, the political authority of S&T has been firmly established. For some time, science popularization has been part of a 'literacy' campaign that aims to

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provide cultural education for the wider population. Both the literacy campaign and the new innovation strategy lay the foundation of what one might call a 'lighthouse model' (see Bauer et al., 2018) of science authority in a Chinese context, in which the vision of science shines a directing light into Chinese society. As the knowledge-producing part of the national innovation system, universities and research institutes are supported mostly by the government. In this case, the science community in China is considered a beacon for the lay public, as suggested by the lighthouse model. However, as we know from other contexts, the formally established authority of science does not yet guarantee the public's endorsement of that authority as a matter of everyday culture. This is what we call the 'cultural authority of science'.

1. Previous research in China on attitudes to science

Although an increasing number of foreign researchers have noted studies related to the public understanding of science (PUS) in China, such studies have been rare. The survey-based research stream of Chinese scholars focuses mainly on the fostering and analysis of 'civic science literacy' in China. As some researchers have indicated, 'Far Eastern countries, such as Japan and China, focus on literacy, and the issue of public attitudes to science is approached with hesitation' (Bauer, Shukla and Allum, 2012).

Ren and Xie (2012) noted that the history of Chinese science communication, which was initially dominated by top-down government concerns, has been adjusted to increasingly meet the needs of a diversifying public audience. Through their analysis of the demand structure of science communication, they concluded that different groups in China have different predilections for the communication channels and lifestyle patterns by which they access relevant information. With the establishment of multiple and more individuated cultural lifestyles, public demand for popular science also tends to become more varied and individualized. In the absence of thorough descriptions and analyses of public attitudes to science in China, their conclusion on changing demands for science popularization strongly suggests the need for such studies. Individuation and diversification can be seen as two hypothetical trends in Chinese attitudes to science, and a basically utilitarian view of science is one key dimension of that orientation.

Li and Yao's research (2014a, 2014b) explored the formation of Chinese public attitudes to science through exploratory and confirmatory factor analysis using several versions of questionnaires in Anhui Province. Their results summarized public attitudes to science in three dimensions: 'emotional experience to science', 'cognition to science' and 'behavioural tendency to science'. With excellent reliability and data fit, Li and Yao believed that their questionnaire was a viable instrument for measuring the public's attitudes towards science. However, based on the three-component attitude theory (affect, behaviour and cognition), the three dimensions had been presupposed, and satisfactory statistical results were obtained only by repeatedly amending the questionnaire. Therefore, whether the conclusion drawn from this context is applicable needs further consideration and discussion. Moreover, even ignoring the sample size of the study, the sampling areas were all within Anhui Province, which limited the complexity of attitudes revealed by the study. Geographical and cultural specifics, even within Anhui Province, would greatly condition the structure of public attitudes to science. When looking at the whole of China, can public attitudes to science simply be summarized by these three dimensions? Is this 3D-structure solid enough to deal with the diversity of the country? These key questions are still waiting for answers from a questionnaire that is used in a nation-wide survey.

Yang (2014) used multivariate regressions to model the factors that influence public attitudes to science. Similarly to Li and Yao's study, Yang also started from the three-component attitude theory and translated Rosenberg and Hovland's classic ternary theory—comprising 'cognition', 'emotion' and 'behaviour' in relation to an object—into 'interest in science', 'opinion about science' and 'concerns about science and science controversy'. Since this translation was made before any supporting evidence was produced, the conclusions seemed premature. The sample for the study (n = 1,071) was collected in the cities of Chongqing, Taizhou and Yichang, similarly to the strategy used in Li and Yao's study. Both studies made reference to the seven waves of China's civic scientific literacy survey from 1992 to 2007; however, they did not mention the eighth survey of 2010.

The series of reports on Chinese civic scientific literacy (He, Zhang and Ren, 2015; Ren, 2010, 2011) edited by the China Research Institute for Science Popularization (CRISP) introduced the nationwide civic science literacy survey in China and stressed, in particular, the results of the 2010 survey. In the first volume of the reports, three surveys conducted before 2007 categorized public attitudes towards science into four types: 'opinion about science', 'cognition on science development', 'attitude to science innovation' and 'ideas about S&T professionals'. In each category, positive and negative descriptions were used. In volumes 2 and 3, 'public attitudes to nature' was added as an index; in volume 3, the description of public attitudes was visualized in graphs and figures, detailed for each province and municipality under the central government.

Previous research (see Gao, Ren and He, 2008; He, Zhang and Gao, 2008; Ren, Liu and Ren, 2015; Wang et al., 2012; Zhang, 1991) based on the scientific literacy surveys in China introduced the foundations for researching public attitudes to science across a timeline of 25 years in China, without further examining the structure of those attitudes. Ren et al. (Ren, Zhang and He, 2014) tried to analyse these structures with two dimensions: 'promise' and 'reservation'. However, there remains a need to see the whole picture of public attitudes to science across China more clearly. Meanwhile, the two dimensions examined in the study are based on the previous observations by Jon Miller (2004) in his comparison of attitudes to science in the United States, the European Union (EU), Canada and Japan. However, Miller's conclusions may need further consideration when they are introduced to China. First, he used two dimensions ('benefit' and 'concern') directly interpreted from people's positive and negative responses in the data to address public attitudes to science in four areas. It appears that interpreting those two dimensions as 'expectation' and 'impact' was unreasonable, especially as only four items out of 15 were selected from the questionnaire to justify the validity of their classification. Second, since the contexts of Miller's study were quite different from China, we need to keep an open mind about whether his structure could be generalized and applied as a model for confirmative purposes in China. In his study, even though he tried to describe a wider image from the data, the attitude measures were restricted within two simple evaluative dimensions, and there was no further exploration of the complex structure of attitudes in cognition, evaluation and behavioural features. Li Daguang (2005) used a similar method to describe public attitudes in China in two dimensions: positive and negative.

Pardo and Calvo (2002) reviewed the measurement and methods of analysis of attitudes to science using the Eurobarometer. They indicated the importance of using qualitative methods in interpreting the survey results. They critically discussed Durant et al.'s earlier structural analysis and considered the latter two of three factors ('progress' 'panacea' and 'future shock'), which drew on

11 items about value and judgment, although that was not clearly stated. They suggested using more rigorous research instruments and more concrete and solid theory building to advance the structural comparison of attitudes to science. Durant et al.'s earlier three dimensions were obtained from exploratory factor analysis; they applied the three dimensions to all countries without distinguishing varied regional conditions. Although Pardo and Calvo (2002) criticized the power of exploratory factor analysis, they admitted that it is an essential first research instrument for analysing public attitudes to science. They also emphasized the complexity of those attitudes and suggested improvements to the 3D category labels, coming up with 'positive', 'negative' and 'ambivalent'.

Based on varied observations of and conclusions about global efforts to survey PUS, Bauer, Shukla and Allum (2012) proposed a future strategy for PUS worldwide. Considering the problems caused by linguistic and cultural differences, they suggested that reanalyses of existing data with different eyes and open minds should be the way forward, not least to solve the problem of functional equivalence in otherwise different questionnaire studies, which is poignantly expressed by the Chinese scholar Cheng Donghong in a cooking metaphor: cooking the same ingredients with different sauces to release new flavours.[2] To develop science culture indicators, they suggested thinking about potential dilemmas between building a campaign guidance system and comparing cultural systems when thinking about research targets for general or specific indicators. From our review of studies of Chinese and foreign scholars, we conclude that most of them have built a campaign guidance system using general indicators. In this study, we introduce a focus on reconsidering the general indicators of new understanding when comparing cultural systems.

Liu, Tang and Bauer (2012) merged the Chinese (Anhui Province) and European data and analysed features of PUS in the two regions. The variables in their study were very similar to those in China's civic scientific literacy survey in 2010, which are used in the present study. Therefore, their methods offered an important 'pilot' for this study. They found 'level of education' and 'urban–rural divide' to be the two most important sociodemographic variables. That insight is used in the present study when exploring public attitudes to science in different areas and among people with very different backgrounds. These two sociodemographic variables add meaning when comparing the geographical variable ('province'). Shukla and Bauer's (2012) conditional transformation method for securing linearity between indicators in different contexts when constructing the science cultural index across 32 European countries and 23 Indian provinces also provides a good model for processing cultural indicators.

2. The structure of attitudes to science in China today

Based on the previously cited studies in China and beyond, this paper tries to answer one question: Given that China is a country with a large population and a variety of cultures, how should its public attitudes to science be described?

Previous studies indicated that scholars had realized the limitation and increasing inadequacy of using a single, one-dimensional model of 'literacy' when describing China's emerging public attitudes to science. Moreover, although fixed dimensions are convenient and easier when measuring and comparing data, such methods would largely ignore the complexity of public attitudes to science across the country. Therefore, in this study, exploratory factor analysis was first conducted to examine the multifarious public attitude structures across China. In a second step, confirmatory factor analysis was conducted to test the fit of a 4D model of public attitudes towards science (see Bauer and Suerdem, 2016; Bauer et al., 2018). On the basis of this 4D model, 32 provincial regions (in which Xinjiang Production and Construction Corps, also known as 'Bingtuan', is treated as an independent region) of China are clustered into two groups with different science culture contexts.

2.1 Overview of the attitudes to science database

The eighth civic scientific literacy survey in 2010 was the largest sample of its kind in this field ($n > 60,000$). It covered all regions of the Chinese mainland and was statistically representative for 32 provincial regions using a three-stage stratified PPS (probability proportionate to size) sampling method. The total sample size was $n = 69,360$; $n = 68,414$ was the final valid sample. Data collection through computer-assisted personal interviews started in March 2010 and continued until October 2010. CRISP officially released the results in November 2010. In this round, the sampling methods were greatly improved compared to the previous seven surveys, not least by increasing the sample size in order to guarantee data reliability for each provincial region by using PPS sampling.

In order to take regional development into account, the 32 provincial regions were classified into four groups according to Renmin University's 2008 RCDI (RUC China Development Index) report (2008):

- Category 1 (municipalities): Beijing, Shanghai, Tianjin
- Category 2 (developed provinces): Zhejiang, Jiangsu, Shandong, Liaoning, Jilin, Guangdong
- Category 3 (central provincial regions): Fujian, Inner Mongolia, Heilongjiang, Shanxi, Hunan, Hebei, Hubei, Henan, Hainan, Xinjiang, Bingtuan, Ningxia, Chongqing, Jiangxi, Guangxi, Shaanxi
- Category 4 (developing provincial regions) Sichuan, Anhui, Qinghai, Yunnan, Gansu, Guizhou, Tibet.

For the first category, a three-stage stratified sampling method—PPS—was directly applied. In the first stage, residential district units (towns) were selected. In the second stage, neighbourhoods (villages) were selected. In the third stage, individual households were selected, and only one respondent was selected in each household. PPS sampling was applied during the first two stages according to the population size. Random-start systematic sampling was applied for the households.

For the other categories of provincial regions (27 provincial regions, except Tibet and Bingtuan), the same strategy was applied. At the first stage, counties were selected; in the second, neighbourhoods (villages) were selected according to the population; in the third, households were selected, and each respondent was selected randomly using two-dimensional stochastic indicator tables.

Tibet and Bingtuan—were treated differently. Only Lhasa city and Shigatse city in Tibet were selected. The sampling strategy was the same as in the first category. Bingtuan has an administrative division different from other provincial regions. At the first stage, divisions were selected, then regiments and finally households. Table 1 summarizes the sample strategy for the eighth civic scientific literacy survey (Ren, 2010).

2.2 Items for analysis

The 2010 scientific literacy survey included several items that are relevant to the analysis of Chinese attitudes to science, including true/false knowledge items, Likert-type evaluations, measures of interest and engagement with science. To indicate 'public attitudes to S&T', we considered four dimensions: knowledge, interest, engagement and attitude.

Table 1: Distribution of sampling for China's eighth civic scientific literacy survey

Category	Provincial region	First stage (PPS)	Second stage (PPS)	Third stage (random-start systematic sampling)	Sample size
Municipalities	Beijing Tianjin	Residential districts (244)	Neighbourhoods (2)	Households (10)	4,880
	Shanghai	Towns (80)	Villages (2)	Households (10)	1,600
Common provincial regions	27 provincial regions	Residential districts (256)	Neighbourhoods (3)	Households (10)	7,680
		Districts/counties (520)	Neighbourhoods/ villages (10)	Households (10)	52,000

We included 12 knowledge items (Table A1). Respondents were asked to judge whether a statement was right or wrong and scored a point for a 'correct' answer. Three items examined interviewees' interest in science and science-related information (Table A2). We combined the responses 'very interested' and 'moderately interested' to indicate interest, which was scored as a binary: 1 for 'interested', and 0 for 'not interested'. Four items examined people's engagement in exhibitory spaces such as science museums, science centres, zoos, aquariums, public libraries and art museums. We focused on engagement with science, including visits to science museums (or centres) and zoos (or aquariums) (Table A3). Similarly to interest, we created a binary variable: 'visiting places' was counted as 1, and 'not visiting' as 0.

Finally, 15 evaluative attitude items entered our analysis (Table A4). They were Likert items with five levels from 'strongly disagree' to 'strongly agree', and 'don't know'. Responses were scored from 1 to 5, and 'don't know' was scored as 3, which was the same as for 'neither agree nor don't agree'. Of the 15 items, four items expressed concern about or negative attitudes to science.

For the final indicator selection, an exploratory factor analysis on the attitude items was conducted; items with factor loadings lower than 0.30 were excluded. Two sets of variables were run: the first included all 15 attitude items; the second included the 15 attitude items, the knowledge score, and the binaries of interest and engagement with science. For comparison with the EU data, a confirmatory factor analysis followed up on 30 indicators that were common between the EU and China. Finally, we identified a viable four-dimensional model of attitude structure, which is the basis of our present interpretation of Chinese attitudes to science.

3. Findings: one size does not fit all

After a set of exploratory and confirmatory factor analysis, four dimensions of attitude structure were reliably identified based on various indicators. We use the following labels to name the four dimensions.

- **Progress (P)**: comprising four items expressing a positive attitude towards S&T. The higher the value of 'Progress', the more positive was the attitude expressed by individual respondents.
- **Reserve (R)**: comprising four items expressing concerns and reservations about S&T and personal or societal development. Higher values meant stronger reservations about science.
- **Knowledge (K)**: comprising six knowledge items with the best item response theory characteristics. Higher values represent higher levels of scientific knowledge and literacy, in the sense of general familiarity with scientific facts.

- **Engagement (E)**: comprising three items of interest in and engagement with S&T activities and venues.

For our interpretation of science culture in China, we followed the MACAS (Mapping the Cultural Authority of Science, an Indo-European led project aims to map the cultural authority of science, and to construct a system of indicators) idea (see Bauer and Suerdem, 2016; Bauer et al., 2018) of considering correlations between the key indicators, and not the level of the indicators. On the basis of this 4D model, an intercorrelation matrix with six correlations was examined for further discussion (Table 2 and Table A5). For the positive and negative interpretation of each of these six correlations (PR, PK, PE, RK, RE, KE), we used the logical form as shown in Table 2 to explain the meaning of the relationship.

3.1 Two clusters for different patterns of science culture authority in China

On the basis of the correlation matrix of the 4D model, cluster analysis was conducted among the 32 provincial regions in China. Six correlations between indicators were identified, marking the science culture in each provincial region. Two regional clusters with different features of science culture emerged from the hierarchical grouping. We applied R software in this study to conduct the analysis and to visualize the results. In the end, three provincial regions were excluded as outliers:

Table 2: Logical form to explain the meaning of the correlations

Correlation	Positive	Negative
PR	People believe that S&T are positive and promising, and they have no criticism of or doubt about them. People's expectation for science is consistent with their attitudes towards science, either positive or negative.	People's expectation for scientific development is not consistent with their attitudes towards science, or they believe in the future of science but have a critical attitude to science (or vice versa).
PK	People with higher knowledge believe more in S&T's promising future, which means that more knowledgeable people have higher expectations.	People's positive view of S&T's future has no significant relationship to their knowledge level. 1. High knowledge with low expectation or negative evaluation. 2. High expectation with low knowledge.
PE	People with a stronger interest in S&T believe more in the promising future that they can bring. More interest with high expectation.	Strong interest in S&T may not lead to a strong positive view on the future that they will bring. 1. High interest with low expectation. 2. Low interest with high expectation.
RK	People with a high level of knowledge lack scientific criticism and have a more positive and unconservative attitude towards science.	People with a higher knowledge level may be more conservative and critical, while those with a low level of knowledge may be blindly optimistic about science.
RE	People with a strong interest in S&T are more likely to lack critical views on them.	Strong interest in science has no relation to critical views on S&T.
KE	People with a high interest in S&T have a higher knowledge level. Knowledgeable and interested.	People with a high knowledge level may not have a strong interest in science. 1. Knowledgeable without interest. 2. Interest without knowledge.

Guangxi, Yunnan and Shanghai. Two typical clusters of different science culture features were evident (Figure 1).

From the hierarchical cluster analysis, two clusters emerged. The two clusters showed opposite correlations among each dimension of public attitudes towards S&T. Cluster 1 shows positive and generally strong correlation of PR, PK, PE and KE, but negative correlation of RE and RK. Cluster 2 shows strong negative correlation for each correlation except RK and RE.

3.2 Two attitude models concerning scientific literacy in China

According to Table 2, in which we tried to interpret the logical meaning of each correlation, we can profile the following two different models of attitudes to science.

- **Chinese attitude model 1 (the classical literacy model):** public attitudes, knowledge and interest in S&T are positively and strongly correlated with each other; all indicators line up in the same direction. This means that people with high knowledge express more positive expectations of S&T and believe in their promising future. They also show higher interest in and greater engagement with science. The more knowledgeable people have more belief in progress.
  These attitudes are mainly presented in Cluster 1, including 19 provincial regions: Beijing, Tianjin, Shandong, Zhejiang, Fujian, Heilongjiang, Jilin, Hebei, Henan, Shanxi, Anhui, Jiangxi, Inner Mongolia, Qinghai, Guizhou, Shaanxi, Sichuan, Chongqing and Bingtuan.
- **Chinese attitude model 2 (the alternative model):** public attitudes, knowledge and interest in S&T are negatively correlated with each other. This means that people who have higher knowledge express more reservations about and critical expectations of S&T, while people with lower knowledge have, quasi-blindly, more positive attitudes towards S&T. Less knowledgeable people have more belief in progress, while knowledgeable people have more concerns and reservations.
  These attitudes are mainly found in Cluster 2, including 10 provincial regions: Liaoning, Jiangsu, Guangdong, Hubei, Hunan, Hainan, Xinjiang, Ningxia, Tibet and Gansu.

Figure 2 shows the values of correlation of 29 provincial regions: the darker the colour, the stronger the correlation. Hunan Province, which is in the central part of China, has the highest value of RE. Anhui Province has the strongest PK correlation.

As to the geographical distribution of the two attitude models, Model 1 occurs mainly in the eastern and central parts of China, which are more advanced in social and economic development; Model 2 occurs mainly in the western areas, which are generally less developed.

To better understand the differences between the two attitude models, we might reflect on two different patterns of the cultural authority of science as it relates to ‘ideal’ or ‘typical’ people:

- Ms Shi Lei, who is 37 years old and lives in Beijing City, is well educated and works in a national academy as a researcher. Shi represents the up-and-coming new middle class in present-day China and lives in a fully urbanized world. She may have the highest level of S&T knowledge and strong interest in science, and be generally positive about S&T developments.
- Mr Liu Shandong is 56 years old, is self-employed and lives in the rural countryside of Liaoning Province (Cluster 2, Model 2). His formal education ended when he left school before his 16th birthday, and he has been working as a

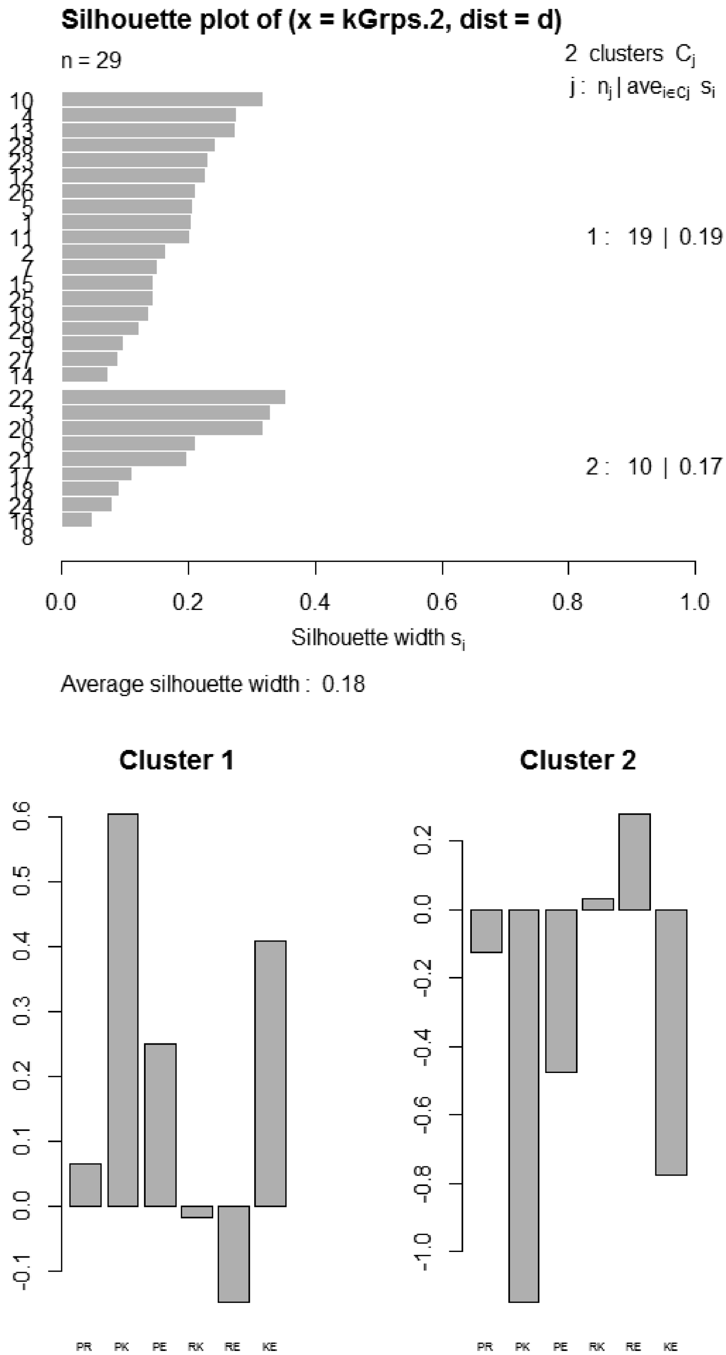

Figure 1: Cluster analysis results of 29 provincial regions in China

Codes for 29 provincial regions: 1-Beijing, 2-Tianjin, 3-Liaoning, 4-Shandong, 5-Zhejiang, 6-Jiangsu, 7-Fujian, 8-Guangdong, 9-Heilongjiang, 10-Jilin, 11-Hebei, 12-Henan, 13-Shanxi, 14-Anhui, 15-Jiangxi, 16-Hubei, 17-Hunan, 18-Hainan, 19-Inner Mongolia, 20-Xinjiang, 21-Ningxia, 22-Gansu, 23-Qinghai, 24-Tibet, 25-Guizhou, 26-Shaanxi, 27-Sichuan, 28-Chongqing, 29-Bingtuan.

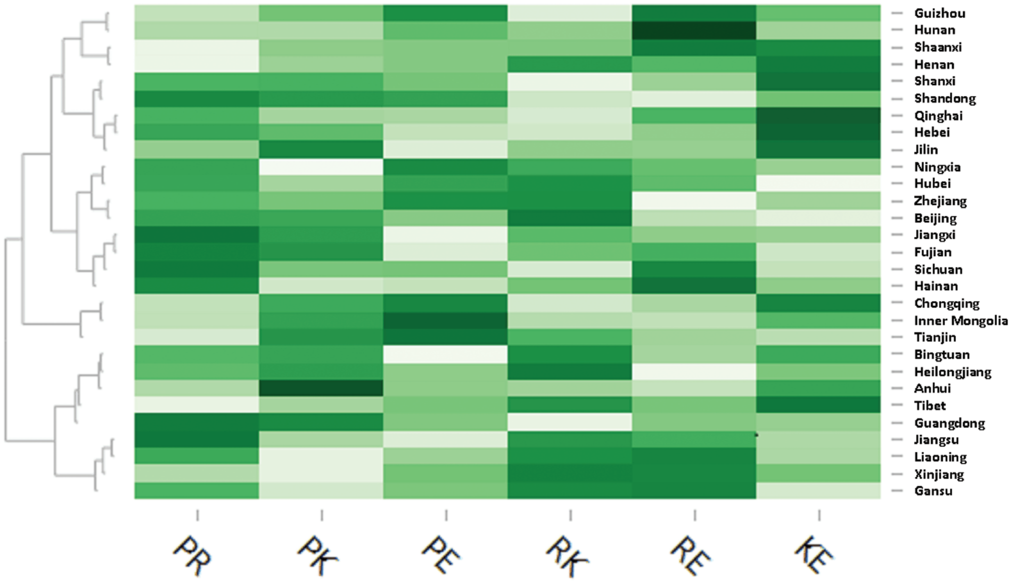

Figure 2: Values of correlation of 29 provincial regions in China

full-time farmer for many years. Because of opportunities for migrant workers moving into the cities, he has found a job in an urban area, where he works during the slack parts of the agricultural cycle, and returns to his rural home during the busy parts of the cycle. He has limited formal scientific knowledge, but may follow the 'lighthouse beacon' of the authority of science in China. He expresses a rather keen attitude towards modern science, but that keenness can border on superstitious or unreasonable expectations. At the same time, he may show little interest in scientific information or daily news, and be unlikely to take part in science culture by visiting museums and exhibitions.

4. Conclusion and discussion

Our research has shown that we need to use more than one model to describe public attitudes to science in China. With certain caveats, the lighthouse model best characterizes the cultural authority of science.

4.1 We need more than one model to characterize public attitudes to science in China

Based on the results of this study, we return to the questions raised at the start. When cooking given ingredients with a new sauce (that is, when rethinking and analysing the existing survey data), do we need general or specific indicators? Do we need a campaign guidance system, or are we to compare cultural systems in the first instance? (See Bauer, Allum and Miller, 2007; Bauer, Shukla and Allum, 2012.)

From the results of this and previous studies, the answer might be: we need both types of indicators.

The general indicator is still useful and meaningful when describing and comparing the public's attitudes to science on a macroscopic scale. Our results support the positive–negative evaluative dimensions of attitudes to science. However, general indicators are descriptors that miss specific features of local culture and concerns; they are the result of approximations for the purposes of better observability and describability.

This paper reflects the contrast between general indicators and specific indicators and shows the meaning of each of them. However, there remains an urgent and important need to develop the research on specific indicators, including the demographic factors that affect the structure of the public's attitudes to science. Since China has followed the Outline of the National Action Plan for Scientific Literacy (issued in 2006) faithfully for a decade, it might now be time to rethink the conception of 'scientific literacy' on a single, one-dimensional measurement model and to introduce more insights on the diversity of modern attitudes in China. That diversity includes views on the authority of science that are manifested in the patterning of knowledge, evaluations, interest and engagement with the world of science in modern life. In that sense, 'one size does not fit all'.

4.2 The lighthouse model may best illustrate the cultural authority of science in China

For the moment, the 'lighthouse model'—the beacon of enlightenment towering over a stormy sea of uncertain attitudes to science (see Bauer et al., 2018)—seems to be the better model to describe the cultural authority of science in China. To some extent, the Chinese Government seeks to boost S&T as part of its development strategy, and this has laid the formal foundation for the cultural authority of science. The cultural authority of science has been strengthened during the past decade, along with the political authority of science.

However, we have also noticed that when specific S&T issues are raised, such as PX (p-xylene) projects or the siting of nuclear power plants in particular neighbourhoods, the 'bungee jump' culture of science can occur.

Therefore, we can summarize the cultural authority of science in China as one in which the lighthouse model is the foundation, and in which 'bungee jumps' will occur in specific circumstances. And, last but not least, the diversity in the culture of science in China must also be considered.

Notes

1 This article was first published as a book chapter in 2018 by Routledge (see Bauer et al., 2018). It is reproduced with permission of the licensor through PLSclear. Necessary edits are made to make it more suitable for republication in the journal.

2 Cheng Donghong's colourful metaphor for the secondary mining of existing civic scientific literacy data was expressed over a dinner discussion at PCST (International Network on Public Communication of Science and Technology) Seoul, in April 2006: 'We have cooked our dish [that is, PUS indicators] exclusively with sweet and sour sauce, but now let us consider cooking it with black bean sauce to discover its real flavour.'

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Appendix

Table A1: Knowledge items

	Question items	Cronbach's alpha if item deleted	% correct
k_earth	The centre of the Earth is very hot.	.750	57.6
k_oxygen	The oxygen we breathe comes from plants.	.770	71.1
k_electron	Electrons are smaller than atoms.	.761	28.1
k_human	Human beings, as we know them today, developed from earlier species of animals.	.761	66.8
k_continents	The continents on which we live have been moving their location for millions of years and will continue to move in the future.	.742	52.8
k_milk	Radioactive milk can be made safe by boiling it	.741	47.1
k_gene	It is the mother's gene which decides whether the baby is a boy or a girl	.747	59.9
k_dinosaur	The earliest humans lived at the same time as the dinosaurs	.743	42.9
k_antibiotics	Antibiotics kill viruses as well as bacteria.	.759	29.9
k_lasers	Lasers work by focusing sound waves	.753	24.9
k_radioactivity	All radioactivity is man-made	.737	50.6
k_time	It takes one month for the Earth to go around the Sun.	.755	39.4
Cronbach's alpha			0.768
Number of interviewees (*n*)			68,416

Table A2: Interest items

	Question items	Cronbach's alpha if item deleted	% interested
int_med_dis1	New medical discoveries	.678	24.8
int_inven1	New inventions and technologies	.508	19.6
int_sci_dis1	New scientific discoveries	.537	23.2
Cronbach's alpha			0.671
Number of interviewees (*n*)			68,416

Table A3: Engagement items

	Question items	% visited
engage_sci1	Did you visit a science and technology museum?	31.4
engage_zoo1	Did you visit a zoo or aquarium?	60.8

Table A4: Attitude items

No.	Question items
D11	Science and technology make our lives healthier, easier and more comfortable.
D12	Thanks to science and technology, there will be more opportunities for future generations.
D13	Even without S&T, people can live very well.
D14	Scientific and technological progress will help to cure illnesses such as AIDS, cancer, etc.
D15	We depend too much on science and not enough on faith.
D21	Science and technology cannot sort out any problem.
D22	The benefits of science are greater than any harmful effects it may have.
D23	Technological discoveries will eventually destroy the Earth.
D24	Scientists should participate in science communication to get people to know more about new developments in science research.
D25	Thanks to scientific and technological advances, the Earth's natural resources will be inexhaustible.
D31	In general, scientific and technological developments will create more jobs than they will eliminate.
D32	Citizens' understanding and support of scientific and technological innovation are the foundation for promoting innovative national construction.
D33	Scientists should be allowed to do research that causes pain and injury to animals such as dogs and monkeys if it can produce new information about serious human health problems.
D34	Even if it brings no immediate benefits, scientific research that adds to knowledge should be supported by government.
D35	Government should engage citizens in science and technology policy decision-making more effectively through a variety of ways, such as hearings.

Table A5: Correlations (strong invariance) and factors scores (base model) of latent dimensions

Region	Correlation value						Mean value			
	PR	**PK**	**PE**	**RK**	**RE**	**KE**	**Progress**	**Reserve**	**Knowledge**	**Engagement**
Beijing	0.436	0.253	0.386	0.344	0.118	0.376	0.063294	−0.04101	0.266031	0.1701
Tianjin	0.21	0.292	0.496	0.293	0.079	0.326	0.147562	0.089266	0.30901	0.244967
Shanghai	0.364	0.2	0.327	0.163	0.131	0.324	−0.02688	−0.21852	0.380096	0.230614
Liaoning	0.347	0.069	0.312	0.257	0.136	0.341	−0.06319	−0.05203	0.058466	−0.00114
Shandong	0.422	0.229	0.392	0.174	0.038	0.399	0.111347	0.087469	0.138785	0.109773
Zhejiang	0.386	0.192	0.403	0.296	0.061	0.392	0.050034	−0.00409	0.146044	0.004942
Jiangsu	0.391	0.109	0.265	0.251	0.105	0.332	0.029349	0.027004	0.264916	0.055287
Fujian	0.43	0.239	0.318	0.26	0.146	0.365	0.115751	0.075383	0.337592	0.176968
Guangdong	0.353	0.164	0.276	0.043	0.027	0.294	−0.15917	−0.11444	0.028551	−0.15636
Heilongjiang	0.33	0.201	0.312	0.3	−0.028	0.361	−0.04722	0.020805	0.12629	0.035516
Jilin	0.346	0.261	0.304	0.239	0.11	0.488	0.004355	−0.00437	−0.00631	0.136139
Hebei	0.361	0.175	0.322	0.193	0.096	0.436	0.062582	0.150346	0.141442	0.163426
Henan	0.339	0.233	0.411	0.353	0.191	0.521	0.199694	0.107102	−0.03695	0.144463
Shanxi	0.392	0.22	0.359	0.104	0.084	0.513	0.093527	−0.02612	0.068378	0.166607
Anhui	0.271	0.192	0.309	0.177	0.044	0.373	0.130889	0.110408	0.043817	0.079161
Jiangxi	0.44	0.226	0.282	0.257	0.102	0.38	−1.48204	−0.57641	0.070753	−0.70266
Hubei	0.406	0.149	0.401	0.31	0.133	0.293	0.122688	0.102611	−0.05986	−0.03783
Hunan	0.294	0.126	0.354	0.21	0.2	0.362	0.151412	0.075528	−0.1006	0.074981
Hainan	0.461	0.102	0.308	0.257	0.226	0.393	−0.33238	−0.36411	−0.15717	−0.2582
Guangxi	0.752	−0.058	0.837	0.02	0.639	0.028	0.222811	0.073753	−0.21938	0.006813
Inner Mongolia	0.181	0.208	0.468	0.106	−0.02	0.381	0.012166	0.060485	−0.08341	0.037386
Xinjiang	0.247	0.037	0.314	0.256	0.124	0.35	0.317458	0.087385	−0.21514	0.191913
Ningxia	0.374	0.041	0.394	0.256	0.104	0.358	−0.01585	0.054579	0.017913	0.057189
Gansu	0.308	−0.011	0.29	0.266	0.143	0.228	−0.07822	0.072832	−0.20078	−0.17899
Qinghai	0.378	0.173	0.351	0.212	0.135	0.459	−0.14835	−0.18733	−0.29853	−0.12378
Tibet	0.12	0.051	0.286	0.236	0.04	0.425	−0.11306	−0.31879	−0.7724	−0.51036
Yunnan	0.19	0.111	0.385	−0.321	−0.108	0.374	0.163461	0.132356	−0.08738	0.058953
Guizhou	0.301	0.189	0.413	0.17	0.187	0.415	0.033766	0.017533	−0.37613	−0.29742
Shaanxi	0.308	0.206	0.382	0.272	0.2	0.477	0.011551	0.024323	0.035135	0.016005
Sichuan	0.423	0.189	0.366	0.202	0.163	0.374	0.153775	0.183768	0.00527	0.086819
Chongqing	0.252	0.199	0.409	0.135	0.058	0.456	−0.03276	−0.02426	−0.35939	−0.347
Bingtuan	0.359	0.211	0.245	0.294	0.072	0.42	0.042823	0.111499	0.106037	0.071538

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The landscape of science communication in contemporary Canada: A focus on anglophone actors and networks

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Abstract

The landscape of contemporary media presents challenges and opportunities for science writers and communicators. These issues have not yet been fully understood. This paper presents the findings of collaborative work conducted to identify the growth in numbers of social media communicators who are writing about science for the Canadian public. We used emerging media research tools, including Altmetrics, and traditional survey tools. Our goal was to help Canada's professional member associations—Science Writers and Communicators of Canada (SWCC) and the Association des Communicateurs Scientifiques du Québec (ACS)—map the changing science communication landscape in Canada. Using an online survey tool, we compared survey responses from social media science communicators we identified to those of professional science communication members of SWCC and the ACS. We found that Canadian social media science communicators were younger, were paid less (or not at all) for their science communication activities, and had been communicating science for fewer years than other science communicators. They were more likely to have a science background (rather than communication, journalism or education) and were less likely to be members of professional associations. They tended to communicate with one another through their own informal networks. These findings provide professional science communication organizations in Canada with an empirical base from which to develop training, support and outreach activities aimed at improving the quality of public engagement with science in Canada.

Key words

Science communication, social media communication, Altmetrics, professional associations, survey methods

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1. Introduction

The rise of social media, starting in the first decade of the 21st century, poses new challenges and opportunities for science communication that are not yet fully understood. The birth of the ‘post-truth’ era has come at a time when science is being made more public than ever before (Piwowar et al., 2017). The so-called Web 2.0 provides the public with access to content and the ability to produce, share and respond to content. The traditional communication that occurs between members of scientific communities has also been affected by more public access to data and scientific information. Science communication has been transformed as multiple sources of information emerge. This could be seen as creating more dialogue between science and society and more collaborative work between non-experts and scientists (that is, citizen science), leading to what some consider to be more democratic access to knowledge and the redistribution of power (Delfanti, 2010).

However, having public access to information may not be enough to transform the culture of science, which involves how science appears, is perceived and is communicated in society. The proliferation of science information produced by many different actors poses challenges for determining the credibility of sources and the accuracy of content. As the boundaries between scientists, journalists and the public become blurred, Brossard and Scheufele (2013) urge scientists and social scientists to develop better understandings of how the public interacts with scientific information to develop more effective strategies for communicating science online.

As Schiele (2018) concludes:

> Unlike the outmoded conception of [the public communication of science and technology] as an exercise dispensing would-be neutral truths to a so-called lay audience, only an approach that fosters a confrontation of ideas between actors engaged in a reflection yields a critical appropriation of knowledge in a world governed by complexity. (pp. 21–22)

2. The changing landscape of science communication

Science journalists have long been recognized as credible agents for transferring knowledge to society, leading them to be considered as elite journalists (Henningham, 1995; Blum et al., 2006). Recently, however, the number of full-time science journalists has declined in many countries, leading some researchers to argue that high-quality science coverage has declined too (Saari et al., 1998; Schäfer, 2017). In addition, researchers have noted that, as the number of science journalists dwindles, science communication is moving from traditional media outlets to online channels (Brumfield, 2009; Allan, 2011; Fahy and Nisbet, 2011). Bucchi (2013) argues that changing media conditions, which include the loss of media filters and processes to guarantee the quality of information, have led to a ‘crisis of mediators’.

The new media landscape undeniably presents new challenges for communicators. For example, science communicators have reported a greater need for images and videos to convey complex scientific content (Pinholster and O’Malley, 2006). There are also additional demands on communicators’ time, as audiences become content producers or co-producers. There is also a greater need, in many cases, for collaborative work with scientists to gain exclusive access to information (Fahy and Nisbet, 2011). Science communicators working mainly in social media environments may also have different interpretations of information quality, accountability and professionalism. For example, Schmidt (2014) has found that social media communicators are more likely to select and display information according to personal relevance, that their content explicitly addresses people in their networks (rather than an amorphous public) and that their content also tends to be more conversational, rather than transmissional. Recent research into the work of scientists as communicators on social media and blogs has also identified a number of motivations for 'scientist' communicators on social media, including self-promotion and influencing public opinion and political decision-making (Allgaier et al., 2013; Besley, 2014; Liang et al., 2014; Peters et al., 2014; Trench, 2012).

Overall, research points to an increasing role for scientists and others in online science communication activities (both a consequence and a cause of the reduction in science journalism). This changing landscape has led some to call for greater public outreach and engagement from these new perspectives (Nisbet and Scheufele, 2009). Bucchi (2017) calls on researchers and institutions to take greater responsibility for producing high-quality science communication and critiquing science where that is needed. If discussions about science in society are to be democratic, he argues, then greater recognition and support may be needed for the growing number of people working outside institutional structures who communicate science in the contemporary media landscape.

In practice, however, the authority and production of content remains with scientists (Besley, 2014) and journalists (Brumfield, 2009). In addition, Peters et al. (2014) emphasize that using social media to communicate science does not necessarily mean finding new ways of producing new content, but rather new ways of sharing it. They argue that the new platforms offer 'new opportunities and options for science to communicate with the public' (p. 752). Social media platforms may provide an increasingly open space for sharing different perspectives and creative endeavours for a wide range of communicators, including research students, artists and communicators who refer to themselves as YouTubers, Instagrammers and storytellers.

At the same time, journalists have also adapted to the new forms of public interaction as a way to invest in more participatory relationships and avoid losing readers and viewers (Holliman, 2011). As the social relevance of science gains prominence, Holliman argues for the need to better engage science and society in digital spaces:

> As science communication teachers, trainers and researchers we need to facilitate strategies where scientists and citizens can engage with the development of digital stories about the sciences, how they are represented in the digitally mediated public sphere, and how audiences consume and respond to them. (p. 4)

While he focuses on dialogue between scientists and the public, it is equally important to consider the social network of science writers and communicators. If, as Weingart and Taubert (2017) argue, trust in science relies on trust in science communication, then an important focus of research is identifying who is communicating science in the changing social media landscape. It is also important to understand what high-quality science communication looks like for these communicators. This may help inform the activities of the professional member associations.

3. The science communication landscape in Canada

As in many other countries, Canada's science communication reflects the early professionalization of science-writing and broadcasting. In addition, increased government investments reflect the recognition that economic and social progress cannot be separated from science and technological progress (Schiele and Landry, 2012). During the latter part of the 20th century, science communication in Canada focused on informing the public, promoting scientific careers to support economic development, and increasing science literacy in the Canadian population.

More recently, Canadian science communication has focused on public engagement, knowledge co-creation (Einsiedel, 2008), and a 'science in culture'—or thinking about how society talks about science (Schiele, 2018). Science communication practices have taken a ‘dialogic’ turn—a term applied by Einsiedel (2008) and documented by others (Phillips, 2011; Fahy and Nisbet, 2011; Braun and Könninger, 2017). Dialogic science communication moves beyond ‘translating’ scientific knowledge for the public and recognizes people’s need for direct engagement with each other in scientific processes and involvement in policy formation (Bucchi, 2008; Stilgoe et al., 2014). That is, a dialogic approach calls for the greater willingness and capacity of science communicators to engage with hard-to-reach audiences. Many of these science communication engagement activities are now initiated or conducted wholly online.

Canadian journalists are also seeing a change in how people prefer to receive news. In 2018, 74% of the Canadian population spent between three and four hours online daily, and nearly 61% of Canadians used social media and the internet to search for news and reports of current events (CIRA, 2018). Canadians prefer to be informed through the media, but at their own time and with little or no cost to themselves (Public Policy Forum, 2017).

Concurrent with the recent rise of social media communication has been a reduction in federal and provincial government support for science and science communication in Canada (Boon, 2017). Yet scientific researchers in Canada are increasingly pressured to demonstrate research impact as part of the current audit culture of research institutes and universities, prompting many to take on roles as ‘scientist’ communicators in social media settings. Along with the dissemination of science through social media, another factor is the blurring of boundaries between institutionalized journalism and communication systems (Rollwagen et al., 2017). Many former science journalists now work as freelancers. In 2015, Rollwagen et al. surveyed Canadian journalists to explore the impacts of the changing media landscape. They found that some of the greatest impacts on the work of journalists were procedural, including access to information, journalistic ethics, media laws and regulations, available newsgathering resources, and time constraints. Many of these procedural influences are quite feasibly different for science communicators working online and outside mainstream journalistic systems.

Professional member associations in Canada recognize that they play an important role in supporting critical innovation in science-writing and communication. Science Writers and Communicators of Canada (SWCC; founded in 1971) is paying close attention to these issues. After much debate over many years, the organization recently changed its name from the Canadian Association of Science Writers to recognize its changing membership base and the important role of science communicators in Canada. Both SWCC and the Association des Communicateurs Scientifiques du Québec (ACS; founded in 1977) are keenly interested in who is communicating science in Canada and how, so that they can better develop new policies and practices. These are two of the most relevant organizations for science communicators in Canada.

Here, we report on the findings from surveys of SWCC and ACS members about their communication practices. We compare their responses to those gathered from Canadian social media communicators, who were identified through social media mapping methods.

4. Identifying social media science communicators in Canada through social media mapping

Veltri and Atanasova (2017) argue that, due to the hybrid and changing nature of social media platforms, science communication researchers have reached little agreement on how to study social media or what can be achieved from its study. They advise researchers to draw on various complementary theories and accompanying methods.

We began this project by identifying Canadian science communicators on Twitter and Instagram, which are two of the most popular social media platforms in Canada (Barata et al., 2018). For Twitter, we obtained data from Altmetrics.com, which produces alternative metrics to track how papers are shared on social media and other online platforms such as Wikipedia, news outlets and blogs (Priem et al., 2010; Adie and Roe, 2013). We identified Twitter science communicators with the tag 'science communicators' using geolocation to narrow the population down to Canadian communicators. We gathered 855,016 tweets between 2015 and 2016 and then tracked keywords and #hashtags related to 'science communicator', in both French and English, on the biographies of Twitter handles. After cleaning the data, we identified a total of 197 unique Twitter IDs.

We used Netlytic software, developed by Ryerson University in Canada, to identify Instagram communicators. General geolocation on Instagram is reported to be around 6%, so we extracted different sets of data using four hashtags: scicomm, commsci, vulgarisation and sciart. We also tracked keywords related to Canada in the biographies of Instagram users as a way to identify their geolocation (provinces, capitals, as well as #cdn, Canadian). After cleaning the data, we identified 59 Instagram science communicators posting from Canada.

The geographical patterns of science communicators affiliated with the two professional associations and those identified through social media methods were similar, with strong concentrations in the provinces of Ontario, Quebec, and, to a lesser extent, British Columbia.

5. Surveying science communicators in Canada

We invited science communicators identified through Twitter and Instagram, together with SWCC and ACS members, to complete an identical online survey. The survey was designed to compare the demographics of these populations, their activities related to science-writing and communication, their attitudes towards science-writing and communication, and their social media practices. We sent out an initial survey invitation and three reminders. We had responses rate of over 25% for each population group (143/524 or 27% of SWCC members; 87/309 or 28% of ACS members, and 74/256 or 29% of social media communicators identified through Altmetrics and Netlytic).

We conducted quantitative data analysis on the responses we received using IMB SPSS 24 statistics software. Qualitative data from the open-ended questions was coded using NVivo 11 qualitative analysis software. Data is reported below as descriptive statistics and associations through cross tabulations (chi square).

6. Demographic comparisons

As Table 1 shows, the demographics of the SWCC and ACS respondents were similar. The ACS group had the highest proportion of respondents who were paid employees, and the social media respondents we identified through social media mapping had the lowest proportion. Over 40% of social media group respondents identified through Altmetrics and other online mapping tools were not paid for their science-writing and communication work.

Compared to professional association members, the social media communicators we identified through new media mapping were more likely to be female. SWCC respondents were more likely than respondents from the social media group to indicate that they earned more than C$50,000 per year (approximately US$37,000) for science-writing or communication work and were more likely to have 10 or more years of experience in the field

Table 1: Relationships between survey respondents from each group and demographic variables

Categories and variables	**ACS (*n* = 87)**	**SWCC (*n* = 143)**	**Social media (*n* = 74)**	X^2	***P* values**
Gender					
Female	53	97	59	8.31	.016
Male	32	44	12		
Did not answer	2	2	3		
Age range					
30 or less	11	19	31	41.59	.000
31–40	28	33	26		
41 or more	46	90	17		
Did not answer	2	1	0		
Province/territory					
Ontario	0	70	50	261.81	.000
Quebec	86	8	3		
Other	0	63	20		
Did not answer	1	2	1		
Employment type					
Employed	49	66	15	41.07	.000
Self-employed/freelance	20	41	18		
Unemployed/unpaid	11	13	28		
Other	7	19	13		
Did not answer	0	4	0		
Average income					
C$50,000 or less	31	48	30	11.77	.019
C$50,001 or more	36	59	12		
Prefer not to say	5	17	4		
Did not answer	15	19	28		
Years of experience					
2 years or less	9	10	14	43.06	.000
2–5 years	17	29	28		
6–10 years	17	27	24		
10 years or more	43	77	7		
Did not answer	1	0	1		
Primary income					
Yes	52	72	30	8.67	.013
No	29	65	44		
Did not answer	6	6	0		
Primary occupation					
Yes	55	84	33	8.98	.011
No	27	52	41		
Did not answer	5	7	0		
Science education background					
Yes	46	62	51	19.40	.000
No	40	59	10		
Did not answer	1	22	13		
Informal network membership	60	20	51	34.54	.000

when compared with respondents from the social media group. There were no significant differences between SWCC members and respondents from the social media group in terms of respondents' main source of income. However, SWCC members were more likely than social media group respondents to state that science-writing or communication was their primary occupation.

Respondents from the social media group were less likely to have a professional background in areas other than science (that is, in journalism, communication, education, public relations or marketing). However, there were no significant relationships between these groups in terms of the level of training they had received (certificate, degree, graduate study and so on). The number of social media respondents who belonged to a professional science-writing or communication association was much smaller than the number of respondents from the SWCC group. We could not demonstrate a statistical difference because we asked respondents only to name the professional associations they belonged to, so numbers were based on counting those respondents who named a professional association. Only 14/74 respondents from the social media group indicated that they belonged to a professional science-writing/communication association. However, social media group respondents were more likely than SWCC members to be involved in an informal network of science writers or communicators. Those networks included informal social media groups, local event groups or groups that informally got together face to face, and ongoing meetings with trusted colleagues and alumni from university and college courses.

7. Communication purposes, challenges and values

The main purpose SWCC members gave for science-writing and communication was increasing public awareness, while ACS members stated that their main purpose was helping the public form opinions. Social media group respondents nominated quite mixed purposes, but when the three groups were compared, the patterns were not significantly different at $P < 0.05$. Similarly, any differences we identified in the patterns of findings associated with the key challenges facing science-writing and communication were not statistically significant. All science writers and communicators identified major challenges associated with funding and time (Table 2).

In an open-ended question, we asked respondents to describe what made science-writing or communication 'good'. For all three groups, *accuracy* was nominated as one of the top five values. Both members of the social media group and SWCC members focused on science-writing/communication that was engaging, relatable and clear. ACS members were the only ones to use the term *vulgarized*, which refers to the use of non-specialized language. Other words associated with 'good' science-writing/communication for ACS members were *targeted*, *rigorous*, and *entertaining*. SWCC members used words associated with storytelling. Respondents from the social media group particularly focused on science-writing/communication that was appropriate to their audience, in terms of language choice.

We also asked respondents to cite up to three groups or individuals who, in their opinion, were engaging in good science-writing and communication practices. In comparison to the social media group of communicators, SWCC and ACS respondents focused more on mainstream journalists, traditional publications and broadcast media. Respondents from all groups included communicators and organizations that aimed their activities at schools and young people, including museums and science centres, and outreach activities from universities and

Table 2: Purposes of and challenges for science communication

Categories and variables	ACS (n = 87)	SWCC (n = 143)	Social media (n = 74)	X^2	P values
Purposes for communicating science					
Inform public opinion	26	9	9	55.65	.000
Public awareness	15	28	12		
Public engagement	2	27	13		
Public enjoyment	8	10	7		
Scientific literacy	17	12	13		
Share science	13	11	7		
Other	5	39	13		
Did not answer	1	7	0		
Adhering to institutional rules/norms					
Yes	18	19	5	5.94	.051
No	65	112	62		
Did not answer	4	12	7		
Competition					
Yes	4	47	24	28.80	.000
No	79	84	43		
Did not answer	4	12	7		
Public criticisms or conflict					
Yes	4	9	8	2.85	.241
No	79	122	59		
Did not answer	4	12	7		
Quality of new media content					
Yes	9	31	18	7.18	.028
No	74	100	49		
Did not answer	4	12	7		
Time to engage on social media					
Yes	17	44	37	19.88	.000
No	66	87	30		
Did not answer	4	12	7		
Time to publish content					
Yes	34	44	38	9.79	.007
No	49	87	29		
Did not answer	4	12	7		
Generating income					
Yes	26	49	42	16.81	.000
No	57	82	25		
Did not answer	4	12	7		
Funding					
Yes	51	41	30	18.86	.000
No	32	90	37		
Did not answer	4	12	7		
Keeping up with technology					
Yes	13	21	5	3.04	.219
No	70	110	62		
Did not answer	4	12	7		

Table 2: (*Continued*)

Categories and variables	ACS (*n* = 87)	SWCC (*n* = 143)	Social media (*n* = 74)	X^2	*P* values
Managing conflicting interests					
Yes	7	15	5	1.00	.607
No	76	116	62		
Did not answer	4	12	7		
Overcoming distrust in science					
Yes	18	31	24	4.54	.104
No	65	100	43		
Did not answer	4	12	7		
Overcoming distrust in new media landscape					
Yes	2	14	12	10.07	.007
No	81	117	55		
Did not answer	4	12	7		
Relying on PR material for content					
Yes	4	6	6	1.75	.417
No	79	125	61		
Did not answer	4	12	7		
Relying on social media algorithms					
Yes	21	15	21	12.68	.002
No	62	116	46		
Did not answer	4	12	7		
Using language of source materials					
Yes	12	5	3	9.63	.008
No	71	126	64		
Did not answer	4	12	7		

research institutes. Respondents from the social media group particularly emphasized the work of 'scientist' communicators who aimed their communication at adults through social media and broadcast media, such as Samantha Yammine (a PhD candidate at the University of Toronto, who particularly targets young women via Instagram), Vicky Forster (a childhood cancer survivor, now a research scientist at the Hospital for Sick Children [SickKids] in Toronto, who communicates via Twitter), Tim Caulfield (a professor at the University of Alberta and the host of the documentary series *A User's Guide to Cheating Death*), and Jennifer Gardy (an assistant professor at the University of British Columbia, who makes regular appearances on the Canadian Broadcasting Corporation's documentary series *The Nature of Things*).

SWCC and social media respondents also noted the good practices of emerging English-language independent online publications aimed at all ages, such as the blogging platform *Science Borealis* and *Hakai* magazine. They also recognized science communication aimed at adults through YouTube and podcasts such as AsapSCIENCE (a YouTube channel created by Mitchell Moffit and Gregory Brown, posting weekly videos that touch on many different science topics) and Jonathan Jarry (a science communicator with McGill University's Office for Science and Society, who hosts a YouTube show called *Cracked Science* and co-hosts the podcast *Body of Evidence*).

8. Social media communication practices and audiences

Unsurprisingly, respondents identified through the social media mapping work were more prolific users of social media for science-writing and communication compared to members of the ACS and SWCC. We could not identify statistically significant patterns in the use of particular social media platforms because the number of respondents from the professional associations who nominated particular platforms was small. However, first preferences for all groups were divided between Twitter and Facebook. Social media group respondents in particular appeared to actively engage in the range of social media platforms we asked them about: Twitter, Facebook, YouTube, Instagram, Google+, Tumblr, Pinterest and Snapchat. SWCC respondents who used social media were more likely to receive funding for social media activities (23/67 respondents) than respondents in the social media group (7/57 respondents) ($\chi^2(2) = 9.00$, $P = 0.011$). Over 75% of respondents from the group identified through social media mapping (50/57 respondents) stated that their social media activities were self-funded or unfunded. Finally, we coded responses to an open-ended question asking respondents in the three groups to explain why they used social media for science communication. Of the top four responses, the first three were common across the three groups:

1. The broad reach of social media;
2. Targeting or engaging with particular interested audiences or communities;
3. Being able to see social media users interact with each other;
4. Marketing or promotion purposes.

In addition, SWCC respondents indicated that they used social media for science communication because it was enjoyable. ACS members also indicated that they also used social media for networking, while social media group respondents used it for maintaining professional connections.

9. Discussion

In this study, we set out to compare survey responses from professional member association respondents to those of science communicators identified through social media mapping. The aim was to help inform Canada's professional member associations about who is operating in Canada's changing science communication landscape. We were also prompted by calls for greater recognition of public engagement and science outreach activities occurring through social media (Nisbet and Scheufele, 2009) and calls for researchers and research institutions to take greater responsibility for the quality of science communication content and to provide critiques when required (Bucchi, 2017). The findings of this project directly respond to those calls.

The respondents we identified through social media mapping were demographically different from professional association members in many ways. Many were 'scientist' communicators or others participating in science communication activities in unpaid or self-funded capacities. Of particular importance, most of the social media science communicators were not affiliated to a professional science communication member organization. They relied more on informal networks to connect with others doing similar work, indicating concurrent streams of activity between professional and informal science communication networks in Canada. These findings are important for those involved in science communication training and accreditation programmes.

We also identified some commonalities across the groups that could represent opportunities for greater connection between these communities and opportunities to bring these communicators together. Peters et al. (2014) particularly emphasize the importance of recognizing the opportunities provided by social media environments. We found that social media communicators and those who belonged to professional member associations faced similar challenges: time and funding were the biggest challenges for all groups. Accuracy in science-writing and communication was a key value for respondents from all groups, as were traditional journalistic values (relevance, accessibility, storytelling, independent research, and credible/trusted sources of information). Language choices (that is, style) associated with user engagement were particularly important for social media communicators. We view these commonalities as opportunities for professional member organizations to engage social media communicators on shared professional standards.

Canada's professional science communication associations could use the findings of this study to inform their future activities, including encouraging a diversity of science-writing and communication practices (without conflating science journalism and communication), making stronger connections with existing informal networks, providing better networking opportunities for science writers and communicators who are working with social media platforms, and promoting the work of freelance science writers and social media communicators.

These organizations could create closer relationships with social media communicators to better understand their professional practices and career trajectories, and exchange experiences on social media, especially considering the variety of media and language used by those science communicators. They could use this information to further strengthen Canada's professional science communication and writing communities, helping to develop training courses for members and themes for future professional conferences related to social media norms and practices. As Schiele (2018) states, the interface between individual expectations and timely access to information is an important focus for science communicators who wish to understand how social media spaces can better function as venues for deliberative discussion.

As time and funding were particular concerns for all science communicators working in social media environments, future research could investigate how social media communicators are balancing the concerns of generating income and increasing demands on their time with producing accurate and engaging science-related content. Building on the work of Rollwagen et al. (2017) and findings from this study, future research could also investigate the professional norms and conduct (such as hype, accuracy and conflicts of interest) of communicators identified through social media mapping efforts.

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Insights from China for a global perspective on a responsible science–society relationship

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Abstract

Ensuring that science meets the needs of society and does so responsibly is a key aim of current European policymaking. Under the label of 'responsible research and innovation', European Union projects, such as the NUCLEUS project, have been funded to both study and stimulate practices for the development of responsible science–society relationships. The NUCLEUS project aims to define a broader cultural, international and enriched perspective on what a responsible science–society relationship entails. In this paper, findings from a comparative case study in China are presented. Practices are analysed at the conceptual, governmental, institutional and individual levels. Our findings show that social responsibility is the key to the science–society relationship, and that science popularization is a means to enhance scientific literacy.

Key words

Responsible research and innovation, science popularization, science–society relationship, social responsibility

1. Introduction

Responsible research and innovation (RRI) has been addressed frequently in recent years. Within the European context, this academic discourse has often included calls for greater attention to science communication as part of building a more responsible relationship between science and society. During the 2000s, a debate on a new science–society relationship emerged from the nanotechnology field. A report published by the British Royal Society and the Royal Academy of Engineering (RSRAE, 2004) discussed emerging nanotechnologies and possible strategies for dealing with them in the future. Interestingly, a prominent place was given to the identification of social and ethical issues involving nanotechnology, and the authors recommended that societal aspects be included when new technologies are developed. They also argued for the promotion of a wider dialogue about

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nanotechnologies and provided suggestions for how to organize it. They called for the responsible development of nanotechnologies. The phrase RRI—now widely used in the European context—was not yet in use.

According to Rip (2014), RRI can be seen as a social innovation that considers new roles and responsibilities for the actors involved. Rip argues that the word 'responsible' obtained its meaning during the late 18th century and that the current phrase, RRI, might be indicative of a next phase in the social contract between science and society or, more specifically, between scientists and citizens. According to Rip, notions such as the responsible development of new technologies and RRI have emerged because it has become clear that scientists cannot leave it to others to consider social, ethical and political issues. Debates in Europe, for example in the 1970s concerning nuclear energy and in the 2000s concerning biotechnology and the environment, made this clear. In addition, current debates in the public domain, for example about climate change, also show that science and society are connected. The phrase RRI developed quickly and within a few years found its place in academic literature (Rip, 2014). In Europe, RRI became synonymous with meeting the needs of society, as, for example, Von Schomberg (2013), Stilgoe et al. (2013) and the European Commission (2017) have pointed out in their individual definitions of RRI.

The work presented in this paper is based on research conducted for the NUCLEUS project, which is a Horizon 2020 project funded by the European Union.[1] The project deals with the practice of RRI and runs from 2015 until 2019. It aims to support academic institutions and researchers in implementing RRI, offering clear recommendations grounded in philosophical analysis and empirical study.[2] Therefore, in the first phase of the project, various studies explored practices of RRI from several perspectives. One of the studies consisted of a cultural adaptation study that looked at the intercultural contexts of RRI, particularly those in China and South Africa (Dijkstra et al., 2017). The research questions for the cultural adaptation study focused on how RRI and other relevant concepts are implemented in those international contexts; what barriers and successes affect the future implementation of RRI; and what can be recommended for the future implementation of RRI in academic settings and research institutes. In this paper, results from the cultural adaptation study of China are presented to promote a greater understanding of RRI.

The remainder of the paper is organized as follows: first, the methodology of the study is discussed; following this, contextual information about China is given; then the findings from the study are presented; and, finally, the findings are discussed in relation to the European context from which the concept of RRI originates.

2. Methodology: a multimethod approach

In order to collect data that could provide enriched insights into RRI, a multimethodological and qualitative approach was decided upon for the study. According to Greene et al. (2001) and Patton (2002), the use of various qualitative methods allows for enhanced validity and credibility of inferences and leads to a more insightful and diverse understanding of a topic. In other words, the collection of data via multiple methods allows for a broader cultural perspective on RRI (Bauer, 2015). The findings, therefore, can lead to a greater understanding of RRI in China compared to that in the European context, and of arguments and motivations relating to RRI practices in China. However, there are also limitations to the chosen methodology. For instance, qualitative research can never be statistically representative, and conclusions should be seen from that perspective.

2.1 Literature review and interviews

For the cultural adaptation study, both a literature review and interviews were conducted.

The literature review involved the analysis of multiple sources of information. Findings have been derived from sources such as academic literature; reports and news articles; policy documents, including regulations and statistical reports; survey results; personal communications; and presentations. A part of the larger NUCLEUS project involved field trips, which aimed to gain insights into the best practices on location. Indeed, the focus was restricted to one particular aspect of RRI per location. The field trip to China looked at public engagement in Beijing. Therefore, the report of that field trip was also included as a source (Mordan and Skeldon, 2016). Another key publication in China and available in English was the book *Communication and Popularization of Science and Technology in China* by Ren and Zhai (2014).

Semi-structured interviews were conducted with the aim of obtaining further insights into practices in China. The questions for the interviews were based on the interview protocol for the European study within the NUCLEUS project, which was developed by researchers from Bielefeld University (Böger, 2017). The questions were adapted after testing. Questions probed for background information; challenges for research and society; engagement; impacts of research on society; governance of research; changes foreseen in current practices and policies; responsibilities; and support wanted or needed. One final question asked what respondents expected from Europe regarding RRI.

2.2 Procedure and respondents for the interviews

Thirty interviews were conducted in China with researchers from various research institutes and universities. The interviews were conducted in the Chinese language and were supervised by one of the authors of this paper. A report was made and translated into English (CRISP, 2017). The recordings of the interviews served as the basis for the analysis. The respondents were given the background of the NUCLEUS project and the purpose of the interview, which was presented as identifying factors that shape the relationship between research and society in universities and research institutes. The interviews lasted for about one hour each. The respondents (19 male and 11 female) were scientists in leading positions, such as professors, associate professors, deans and directors. Their ages ranged from 29 to 76 years. Twenty-two respondents worked at universities, while eight worked in research institutes in Beijing. Their fields of research varied and included statistics, robotics, seismology, water resources, education, stem cell research, transportation and agriculture.

2.3 Analysis at different levels

As already stated, various definitions of RRI have been used. Definitions of RRI used by Von Schomberg (2013) and the European Commission (2017) emphasize an approach in which societal actors are stimulated to work together during the whole research and innovation process. According to the European Commission (2017), this can include engaging society more broadly in research and innovation practices; increasing access to scientific results; enhancing gender equality both in the research process and in research content; paying attention to ethical aspects in research; and promoting formal and informal science education.

This study specifically used the definition provided by Von Schomberg (2013):

> Responsible research and innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical)

> acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society). (p. 19)

Von Schomberg's definition was used in conjunction with the ideas of the European Commission (2017) concerning RRI and guided the analysis. As a result, specific attention was also given to equality and diversity rather than to gender alone. Furthermore, science education, outreach and open access (which were considered part of research and innovation), stakeholder and public engagement, ethics and broader impacts were considered. In the case study, information about practices was collected and analysed at four levels: conceptual, governmental, institutional and individual. The analysis was executed as an iterative process. The findings from the literature review and the interviews are described together. The analysis at the four levels provided a framework for obtaining deeper insights into how RRI, and thus the science–society relationship, are shaped in China in comparison to Europe as described by, for example, Rip (2014).

3. A context for RRI in China

This section provides a brief outline of how the relationship between science and society in China has developed over time.

China became an upper-middle-income country (Cao, 2016) with a mixed economy following reforms in the 1980s and 1990s. While economic growth in the 1990s was on average almost 10% per year, by 2016 it stabilized at a rate that became known as the 'new normal'. China became the world's second largest economy in 2010 (as measured by gross domestic product). However, according to Cao (2016), China is also facing several challenges relating to inclusive and green development, an ageing society and the middle-income trap. Therefore, an ambitious reform agenda with a strong focus on innovation through science and technology (S&T) has been proposed, as set out in China's 13th Five-Year Plan (Cyranoski, 2016).

For many years, China has invested considerably in science, technology, innovation and education (OECD, 2015; IMF, 2018). Attitudes towards S&T and innovation have been positive since 1978. This is partly because the Chinese people have witnessed and experienced the power of S&T, which have greatly changed their lives and the world around them, and partly because of long-term advocacy that has established a positive image for S&T among the people. Nowadays, public attitudes to S&T have become more and more objective, but social expectations of S&T are still strong. Chinese people trust in science, which forms a favourable environment for the development of technology. According to the central government, China should now focus on integrating innovation with socio-economic development and constructing a favourable environment for innovation by, among other things, opening up and engaging in international cooperation. This also means that research should contribute to economic growth rather than remain a purely academic endeavour—a move that has been described as weaving together 'two layers of skin'. This is important because, according to Cao (2016), China still depends partly on input from abroad for innovation. Innovation alone, therefore, is not enough; among other things, stimulating scientific literacy is considered important to strengthen development.

4. Results

In this section, results from both the literature review and the interviews are presented. After presenting findings about the RRI concept and findings relating to the different practices of RRI at the governmental, institutional and individual levels, it examines the question of what Europe can or should do in RRI.

4.1 RRI at the conceptual level

According to Turnheim et al. (2014), the phrase 'responsible research and innovation' has only recently begun to be used in China. Indeed, a search for Chinese academic papers using the term returned only 18 results. This does not necessarily mean that practices do not align themselves with the idea of a responsible science–society relationship. A more cautious interpretation could be that the practice of RRI in other cultural settings, such as in China, is conceptualized in other terms.

For example, for years the Chinese Government has encouraged scientists to involve themselves in science popularization and communication as part of their social responsibility. The purpose has been to establish a long-lasting relationship between research and science popularization, thus enhancing scientific literacy (Ren and Zhai, 2014). This means that every researcher is responsible for communicating their research (Cheng and Shi, 2008; Yin, 2016). In the interviews, most respondents agreed that the purpose of research is to serve society and lead societal progress. This applied to all disciplines, since this purpose is independent of the type of research. Only a few respondents thought that research could not involve social responsibility. Those respondents stated that only by using research could right or wrong be done; therefore, they believed that responsibility lay with the users (CRISP, 2017).

Science popularization refers to a kind of activity or tool, rather than to a theory, and is the main concept used in China, according to Xu et al. (2015). In the literature, the focus has been on notions such as scientific popularization, scientific literacy, popular science publishing and science communication (Jia and Liu, 2014; Wu and Qiu, 2013; Xu et al., 2015; Zhang, 2015). Public engagement was seen as influencing decision-making and, more broadly, as influencing engagement in science communication activities, in which large groups were actively participating. Xu et al. (2015) concluded that a shift from public understanding to public engagement was taking place, but that China might not have kept pace with such developments internationally. Environmental issues and biotechnology, according to those authors, were topics about which engagement was happening spontaneously.

Turnheim et al. (2014) stated that related concepts, such as responsible research, research ethics and S&T studies, have been discussed for some time now. They indicated that science and innovation policy and, similarly, research and innovation are driven strongly by economic development. Furthermore, S&T are considered to be the driving forces behind economic and social development. Finally, according to Turnheim, China is governed by a top-down decision-making system with a strong state, but changes have been observed as the public has become more aware of risks and rights and more interested in social and ethical questions to do with innovation and technology. In addition, the government is trying to involve more parties in distributing the benefits of science and innovation in such areas as health, the ecological and environmental sciences and public security. They noted that researchers are becoming more aware of research ethics and integrity. According to Turnheim et al. (2014), major Chinese S&T institutions have issued codes of conduct to tackle scientific misconduct (see also Hvistendahl, 2015). The Chinese Government is also taking steps to prevent fraud. Finally, the development of RRI is stimulated by international projects such as Global Ethics in Science and Technology and Promoting Global Responsible Research and Social and Scientific Innovation, which are collaborations with the Chinese Academy of Science and Technology for Development and the Chinese Academy of Social Sciences (Turnheim et al., 2014).

In addition, according to Li Zhenzhen and Leng Min (2016, personal communication), engagement in China is mainly in the style of science popularization and communication. Recently, scientists have become more active and reflective, which is shown by two examples. First, in 2008, citizens were shown to be capable of contributing in a significant way to a consensus conference on the topic of genetically modified food. Second, in a role-change event in which scientists and journalists swapped roles, both parties learned a lot from each other's experiences. From the interviews, it emerged that respondents expected people's desire to engage with research to increase with greater levels of literacy (CRISP, 2017).

4.2 RRI at the governmental level

Attention to science popularization and science communication has increased rapidly during the past 30 years. The popularization of S&T is part of a national strategy that is reflected in various policy documents. For example, the *Law of the People's Republic of China on the Popularization of Science and Technology* was introduced in 2002. It is the only law concerning this topic and aims to promote science and innovation through science popularization. This law has been a driver for programmes and outlines for science popularization and communication, which have doubled in number since its introduction. To further stimulate science and innovation, it is expected that this legislation will be reformed in the future (Ren Fujun, 2016, personal communication).

In addition, in 2006, the *Outline of the National Scheme for Scientific Literacy (2006–2010–2020)* was issued. The outline emphasized the great importance of scientific literacy for the development of citizens and for the building of Chinese society (State Council, 2006). As Cheng and Shi (2008) stated: 'Science researchers and organizations, partly through their involvement in science communication, should take up their social responsibility to engage in science education.' (p. 161). The outline described missions and measurements to stimulate improvements in the quality of science, to promote technological education and training, to develop resources for dissemination via mass media and to build infrastructure for science popularization. Various groups in society are addressed, particularly young people, farmers, the urban workforce, leading cadres and public servants (Ren and Zhai, 2014).

An important recent policy document is *The 13th Five-Year Plan for Economic and Social Development of the People's Republic of China*, which was launched in 2016 (CCTB, 2016; Cyranoski, 2016). It emphasizes the roles of S&T and science popularization in helping to foster innovation. S&T and science popularization are the 'two wings' needed to achieve innovation and development. Various respondents from the interviews pointed to these policy measures. The plan includes efforts to promote research integrity and ethics as well as training researchers on the topic (CCTB, 2016; Yin, 2016). Finally, in 2014, the government document *Guiding Opinions about Establishing the Reporting System of S&T Projects* required state-funded S&T projects to report summaries of projects, which are to be available for open access.

The respondents mentioned various policy documents that they believed would help tackle some of the current challenges for research. *Proposals on Implementing the National Strategy of Innovation Driven Development* shows the importance of innovation in science research (CRISP, 2017, p. 10). *A Scheme to Stimulate the Transformation of Technological and Scientific Achievements* (issued in May 2016) aims to stimulate the application of scientific results to society. *Proposals on Further Improving National Financial Administration of Science Research Policies* (issued in July 2016) will ease administrative tasks and, therefore, could help to tackle the administrative burden and problems such as plagiarism. Finally, respondents expected positive changes such as equal access to universities and policies that will enhance research so that it can become more open to society.

4.3 RRI at the institutional level

At the institutional level, RRI is reflected predominantly in science popularization and communication, which aim to increase scientific literacy. A systematic approach to science education and training is described in the *National Scheme for Scientific Literacy*, for example in the section on the project for S&T education and training (State Council, 2006). As a result, many organizations have established their own bureaus or departments for science popularization and communication, the duties of which are to communicate and disseminate science. For example, the Chinese Academy of Sciences has founded the Bureau of Science Communication.

Various activities are organized at the national, community and local levels. At the national level, two big science popularization events take place each year. In the third week of September, science festivals, of which the biggest is the Beijing Science Festival, are organized all over the country. This effort includes National Science Day. To stimulate professional development and increase knowledge about the festivals, a training programme and evaluations are organized by the coordinating body, the Beijing Association for Science and Technology (BAST). They include a round-table conference, where knowledge and experiences of science festivals all over the world are exchanged. In addition, each May the countrywide Science and Technology Week is organized. In 2015, according to the Ministry of Science and Technology, this event involved more than 177,000 activities and attracted 157 million visitors. At the community and local levels, multiple activities are organized throughout the year, such as lectures, open-door labs, 'big-hands, small-hands' events, summer and winter camps, anniversaries and other public engagements.

Furthermore, science museums, parks, popular science education bases and mobile S&T exhibitions show how science popularization and communication are institutionalized. According to Ren and Zhai (2014), in 2009, China was home to 618 S&T museums, which have a flagship role in educating and engaging the public. Mobile facilities are popular in remote areas. Ren and Zhai also emphasized that the importance of public participation through interactive activities is recognized and that, increasingly, many facilities now include hands-on experiences, which members of the public consider to be highly attractive.

Television and newspapers were the main media channels for science popularization in 2011 (CRISP, 2011), when China Central Television was broadcasting more shows and programmes on S&T than ever before. However, internet-based science communication and popularization are increasingly gaining attention due to communicators' ability to use multimedia—with their high speed, large capacity and high degree of interaction—to inform and to explain policy. Ren and Zhai (2014) stressed the importance of setting up mechanisms that train scientists in science communication and teach journalists how to use the knowledge of scientists.

According to those interviewed, universities as institutions have a responsibility to provide researchers with, for example, communication platforms from which they can conduct science communication. Online courses and training programmes are also appreciated. Furthermore, universities should also support their researchers in communicating their findings and help them to popularize their results. Experiences and ideas could be exchanged on an internal platform, while interdisciplinary collaboration could give researchers the chance to learn about the effects of science communication. Implementing relevant policies at universities could also encourage researchers to publish the negative impacts of their research for educational purposes. Some respondents were also keen to help students balance their research and educational tasks (CRISP, 2017).

4.4 RRI at the individual level

A survey of Chinese citizens in 2010 showed that they strongly supported S&T (74.8%), even if it does not bring immediate benefits (CRISP, 2011). They agreed that research that adds to knowledge should be supported (77.0%) and that government should enable public participation in decision-making about S&T (72.6%). The respondents also agreed that scientists should participate in science communication (70.9%).

The results from 2011 were confirmed by the interview findings analysed in this paper. Respondents agreed that researchers should contribute to science communication (CRISP, 2017). They also believed that researchers have a responsibility to popularize their findings through various means, for example via lectures, social media or contributions to discussions in locations where top research is conducted. In addition, respondents believed that researchers should translate their research and address, for example, leaders and cadres who can serve as intermediaries between the public and policymakers. In this way, researchers should try to influence decision-makers. Respondents also believed that both multidimensional and transdisciplinary research should be stimulated at various levels, which would provide further opportunities for researchers. However, a few respondents disagreed, arguing that this should not be a task for researchers and that professional communicators should assume responsibility for it (CRISP, 2017).

In addition, respondents believed that the administrative and managerial process for research needed improvements so that researchers could spend their time both conducting and communicating their research. For a sustainable relationship between science and society, researchers are responsible for keeping up standards of good conduct and research ethics. Government should guide researchers by issuing regulations, for example. Ethics training and education would make researchers more aware of good scientific conduct. Furthermore, the awarding of monetary prizes could not only stimulate research but also promote science communication, thus enhancing a socially responsible role for science.

4.5 Expectations of European RRI

Respondents were also asked about their expectations of European RRI. One view was that European responsibility should not be restricted to Europe only, but extended to the rest of the world. It was believed that open access and the practice of sharing scientific results with researchers in developing countries should be considered. Respondents thought it was important that research results be communicated, for example, when they concerned results from environmental research, such as that concerning air pollution. Insights could be shared in a repository or library, which would contain examples of how research could help develop society in a positive way. However, it was believed that controversial research findings should also be included, so that lessons could be drawn from them (CRISP, 2017).

For the future, some respondents expected less governmental guidance and more market-driven research. However, they unanimously agreed that scientific research into human safety, such as studies in medical cloning technology and transgenic research, should be conducted only under strict regulations. Respondents also expected science communication to increase considerably and believed that researchers should be allowed the time and conditions to put their efforts into it (CRISP, 2017).

5. Conclusions and discussion

This study aimed to provide an enriched understanding of what responsible science–society relations entail. In other words, as Rip (2014) stated, it sought to determine what roles and responsibilities actors have in the science–society relationship. In particular, the research questions sought to understand how RRI and other relevant concepts are implemented in international contexts, based on the example of China; what barriers and successes affect the future implementation of RRI; and what can be recommended for the future implementation of RRI in academic settings and research institutes. Therefore, this project collected data on practices of RRI in China at the conceptual, governmental, institutional and individual levels, in addition to information about expectations of European RRI.

At the conceptual level, RRI is a relatively new concept in China. The term 'social responsibility' is preferred, which in practice can be translated into science popularization and communication. An important aim is to increase levels of scientific literacy. Most respondents agreed that they have a responsibility to society to popularize and communicate S&T, while a minority disagreed, considering this to be the task of professional science communicators. Examples show that there are more and more public engagement activities, the main aim of which is to raise public scientific literacy through popularization and communication, allowing the public to become more skilful and confident when faced with science-related issues.

At the governmental level, policies focus strongly on innovation with the aim of fostering the economy. Science education inside and outside schools is a means to achieve innovation, and increasing scientific literacy is considered to be an important component of this. In various policy documents, such as the *Law on the Popularization of S&T*, the *National Scheme for Scientific Literacy*, the *13th Five-Year Plan* and state policies, plans for science popularization are detailed for various groups in society. In newer plans, research integrity and ethics are also promoted, along with training for researchers to allow them to become more aware of the importance of good conduct. According to the respondents, governmental policies should help researchers to fulfil their tasks of conducting research, translating the outcomes to society and communicating their results. Fewer administrative tasks and more training in communication and support via awards would also help. Respondents supported the development of S&T and agreed that government should stimulate public participation in research.

At the institutional level, science popularization and communication are institutionalized via official activities such as science festivals and initiatives such as Science and Technology Week, and also through science museums and media channels. In addition, many activities at the local level are supported institutionally. National institutes such as BAST and CRISP are helping to stimulate science education and a greater understanding of science. Many organizations, such as the Chinese Academy of Sciences, have their own offices for science communication. According to the respondents, research institutes and universities should help researchers to fulfil their responsibility to society by reducing the administrative burden of academic positions, providing platforms on which experiences can be exchanged, and offering training programmes to enhance skills in science education.

At the individual level, respondents agreed that their role could be interpreted as a responsibility to society. They would also appreciate support via policy measures and training.

For European researchers, some lessons can be learned. Above all, their responsibility should also include a broader social responsibility towards the world. Sharing results and best practices with developing countries is regarded as valuable and helpful. RRI can take shape in different ways, as can be seen in the concepts, policies and practices in China. According to practical experience, responsibility includes openness towards societal influence and, for researchers, should be more than a checklist of elements.

To conclude, the results of this study have provided an enriched insight into aspects that play a part in the science–society relationship. The case of China shows that RRI can be, and is, labelled differently from RRI in Europe. In China, RRI is framed as a social responsibility, with an emphasis on science popularization and communication. China's policy measures strongly focus on innovation that benefits the country. For example, scientific literacy programmes and science popularization are methods to achieve this. Recently, ethical conduct has gained more attention, and researchers now expect support from governmental policies and their own institutions. This could be offered through the creation of platforms for knowledge exchange, training programmes and training awareness. Respondents also believed that controversial research should be communicated for educational purposes. Therefore, researchers are actively involved in fulfilling their socially responsible role. Overall, the results from the study can be considered insightful. However, qualitative findings such as these can never be conclusive. Further research and comparisons with the European situation are therefore recommended.

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Notes

1. NUCLEUS has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 664932. The acronym stands for New Understanding of Communication, Learning and Engagement in Universities and Scientific Institutions.
2. NUCLEUS proposal, p. 10.

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Cultures of Science is an international journal that provides a platform for interdisciplinary research on all aspects of the intersections between culture and science.

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