CLIMATE outreach

Communicating Environmental and Sustainability Science

Challenges, opportunities, and the changing political context

This report was commissioned by Mistra, the Swedish Foundation for Strategic Environmental Research, ahead of a possible research initiative on Environmental Communication. All but the specific recommendations to Mistra have been published here.

Climate Outreach

Climate Outreach are a team of social scientists and communication specialists working to widen engagement with climate change beyond those who consider themselves environmentalists. Through our research, practical guides and consultancy services, we help organisations communicate about climate change in ways that resonate with the values of their audiences. We have over 14 years experience working with a wide range of international partners including central, regional and local governments, international bodies, charities, business, faith organisations and youth groups.

The Old Music Hall, 106-108 Cowley Road, Oxford OX4 1JE, UK

+44 (0) 1865 403 334
info@climateoutreach.org
www.climateoutreach.org
@ClimateOutreach
Climate Outreach
Climate Outreach

Project team

Authors

Dr Adam Corner, Research Director, Climate Outreach
Dr Chris Shaw, Senior Researcher, Climate Outreach
Jamie Clarke, Executive Director, Climate Outreach

Editing & Production

Anna Stone, Research Coordinator, Climate Outreach
Léane de Laigue, Head of Communications, Climate Outreach
Karl Dudman, Communications and Research Volunteer, Climate Outreach
Elise de Laigue, Designer, Explore Communications – www.explorecommunications.ca
Stephen Longwill, Designer and Illustrator – www.stephenlongwill.co.uk

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EXECUTIVE SUMMARY

This report summarises and synthesises key trends, themes and findings in the field of science communication, with a particular focus on evidence from environmental and sustainability sciences. The report pays equal attention to the study of communicating scientific evidence, and the socio-political context in which science communication research is funded and science communication practice takes place. It maps existing research and capacity (journals, institutions, programmes, key publications, think tanks), reviews existing literature (a high level synthesis drawing on existing summaries) and notes areas for future research.

As the evidence reviewed in this report shows, whilst the accumulated knowledge about communicating and engaging around environmental science topics is vast and well-developed, the field is far from settled, and considerable challenges remain in terms of public engagement on a range of scientific issues, in countries around the world.

Key findings in the report include:

- Science communication is a fractured field, both in terms of where research is published (within academic journals), and which methodology approaches are used. There is little in the way of coordination between different approaches, organisations and centres of expertise.
- Calls to move from the notion of one-way 'communication' to dialogue-based engagement now date back 20 years, but many science communication strategies still focus on 'getting the facts across more clearly'.
- There is growing importance attributed to using frames and narratives to align messages with the needs, values and identities of different audiences for communicating environmental science effectively. However, applied research exploring how frames and narratives about environmental science are received by different audiences is still rare.
- Challenges around communicating uncertainty and scientific consensus are widespread, but there are risks in relying on simplistic messaging strategies to overcome what are often deep-rooted values-based divides.
- The role of trust in building public engagement with scientific evidence, in the context of the so-called 'post truth' turn in public and political discourse, is critical. Scientists are highly trusted communicators in general, but not across all socioeconomic groups, and there is a lack of diversity (gender and ethnicity) within the field of science communication.
- The responsibility for science communication typically lies with individual scientists or specialist organisations/networks. There is a lack of institutional capacity within research centres, but also a lack of 'boundary organisations' that can effectively bridge the gap between research and practice.

INTRODUCTION

A broad consensus has emerged over the past few decades that effective science communication is not a one-way process, and that public controversies about scientific issues are not straightforwardly attributable to a lack of knowledge among the general public (the so-called 'deficit model' of science communication - Sturgis & Allum, 2004). Instead effective science communication is increasingly seen as requiring a two way conversation or dialogue, and is more usefully conceptualised as 'engagement' (Kahan & Carpenter, 2017; National Co-ordinating Centre for Public Engagement, 2017; Parkhill et al., 2013; Corner & Clarke, 2016; Hagendijk & Irwin, 2006; Rowe & Frewer, 2005; House of Lords, 2000; Irwin & Wynne, 1996; Renn, Webler, & Wiedemann, 1995). As the evidence reviewed in this report shows, whilst the accumulated knowledge about communicating and engaging around environmental science topics is vast and well-developed, the field is far from settled, and considerable challenges remain in terms of public engagement on a range of scientific issues, in countries around the world.

Aims of this report:

- To provide a concise but thorough **summary of the current research evidence** on communicating environmental and sustainability science, and relate these to the challenges faced by science communicators.
- To pay particular attention to the **challenges and opportunities** of environmental science communication in a changing political context.

The research evidence examined in this report addresses the themes which we have identified as offering the most valuable focus for future research, given the growing agreement around the need to move from communication to engagement.

Sources for this report:

The analyses and recommendations provided in this report are derived from a review of the current state-of-the-art in science communication research and practice.

On the following page, we present information on key sources that informed this research project: three key expert reviews of science communication, as well as six experts in the field who were interviewed for this work.

"Effective science communication is increasingly seen as requiring a two way conversation or dialogue."

Three recent expert reviews of science communication

A full bibliography is provided at the end of the report, but here we list three recent reviews of science communication and public engagement that are of particular significance and relevance for the themes addressed in this report. These three reviews demonstrate that the field of science communication is well-developed and mature.

Authors	Review title
Nisbet, M and Markowitz, E (2016)	*Strategic Science Communication on Environmental Issues. Commissioned White Paper in Support of the Alan Leshner Leadership Institute.* American Association for the Advancement of Science.
National Academies of Sciences, Engineering, and Medicine (NASEM; 2017)	*Communicating Science Effectively: A Research Agenda.* Washington, DC: The National Academies Press. doi: 10.17226/23674.
HM Government, United Kingdom (2017)	*Science Communication and Engagement Report.* UK Parliament Science and Technology Committee. https://www.publications.parliament.uk/pa/cm201617/cmselect/cmsctech/162/16201.htm

Interviewees

In addition to the literature reviewed, interviews were carried out with six leading science communication academics and practitioners from Europe and the US, which we draw on throughout this report. These 30 minute informal telephone interviews were conducted to ensure that this paper was addressing what is felt to be the most pressing issues in science communication.

Interviewees	Position/Organisation
Maria Gunther	Physicist and Science Editor at Dagens Nyheter (Swedish daily newspaper)
Matthew Nisbet	Professor of Communication Studies, Northeastern University, US.
Robert Watt	Director of Communication, Stockholm Environment Institute.
Brigitte Nerlich	Professor of Language and Communication, University of Nottingham, UK
Victoria Wibeck	Professor of Communication, Linkoping University, Sweden
Kjell Asplund	Professor emeritus at Department of Public Health and Clinical Medicine

Science communication: from information to dialogue

What is science communication?

Science communication is an umbrella term covering a wide variety of activities including professional communication by scientists; interactions between scientists and members of the public; media representations of science; and the ways people use scientific knowledge in their own lives (Mellor & Webster, 2017). The study and practice of communicating science has a long history (Guenther & Joubert, 2017). Public debates about scientific issues are increasingly widespread and prevalent, involving politicians, journalists, and citizens groups (Brown, 2015; Corner & Hahn, 2009; Sarewitz, 2011).

Consequently, there is now a growing expectation that scientists communicate their findings and provide public access to their data, and an awareness among the scientific community that being a scientist often involves much more than simply conducting research according to the scientific method (NASEM, 2017). The global March for Science events (held during the first half of 2017 in response to widespread concerns that scientific funding, culture and method are increasingly under attack) are just one high-profile example of the central role that is now placed on communication, outreach and engagement by the scientific community.

The field of science communication – research and practice – is characterised by a multiplicity of approaches (Carvalho et al., 2016; Corner & Hahn, 2009; Kuhberger, 1998; Lakoff, 2010; Moxey et al., 2003; Pearce et al., 2015; Rothman et al., 2006) and a dense literature.

The different approaches include:

- A substantial philosophical strand on science as an epistemology (Knowles, 2003; Chalmers, 1992; Kuhn, 1970; Popper, 1959), with the unique position of the scientific method in society illuminated by contemporary debates about so-called 'fake news' and 'alternative facts.'
- Competing sociological accounts of how controversy and consensus develop in science (Brante et al., 1993; Collins & Pinch, 1993; Irwin & Wynne, 1996; Dunlap & Brulle, 2015).
- Media analyses of the roles of different groups in the production, communication, and consumption of science (Friedman et al., 1999; Whibey & Ward, 2016).
- Extensive psychological and social-scientific literature on public understanding of a range of environmental science-based topics (Nisbett & Markowitz, 2016), as well as strategies and methods for engaging with publics more effectively (the 'science of science communication' – Fischhoff & Scheufele, 2013; Pidgeon & Fischhoff, 2011).
- Growing interest in environmental and climate change science communication outside of developed nations (Guenther & Joubert, 2017), including South America (e.g. Takashi & Martinez, 2017; Velez et al., 2017) Africa (e.g. De Mulder et al., 2014), China (Chung-En & Zhao, 2016) and India (e.g.Thaker et al., 2017; Olofsson et al., 2017).

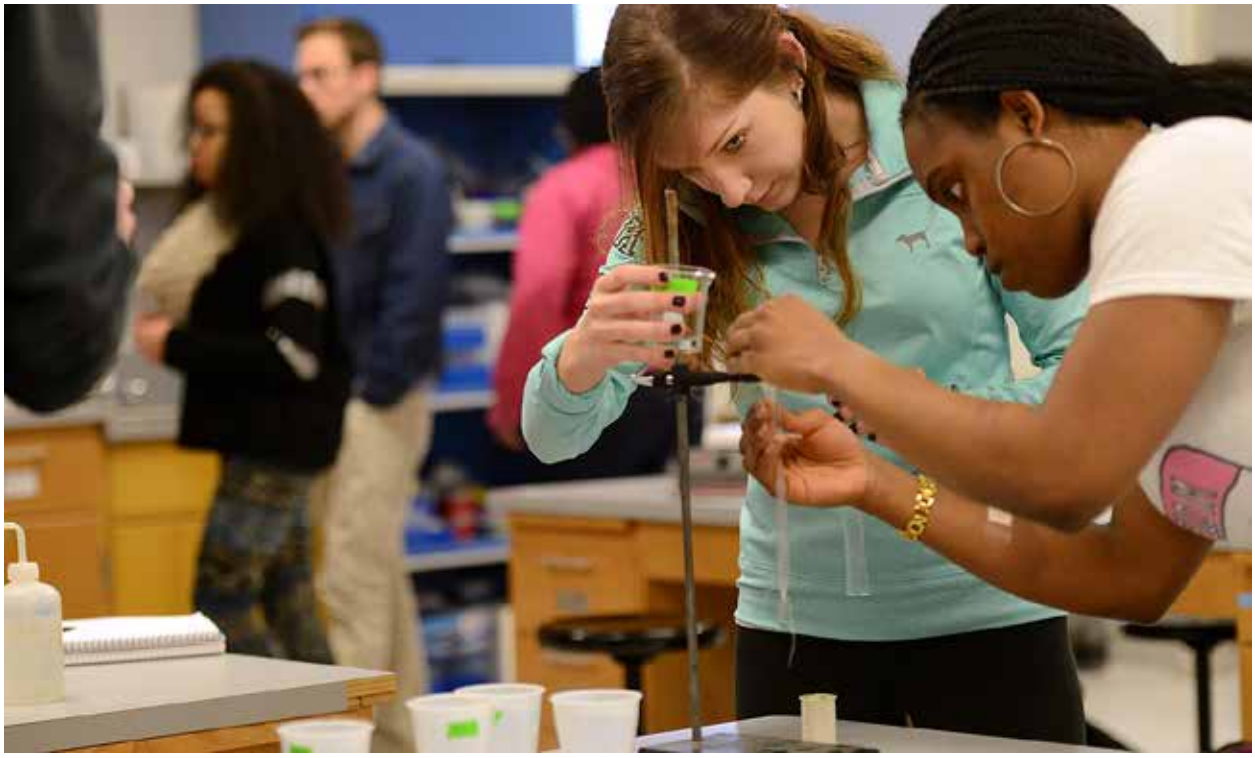
From communicating information to engaging in dialogue

A consensus has emerged over the past few decades that effective science communication is not a one-way process – and public controversies about scientific issues are no longer seen as straightforwardly attributable to a lack of knowledge (the so-called 'deficit model' of science communication – Sturgis & Allum, 2004). Instead, effective science communication is increasingly seen to require a two way conversation or dialogue, and is more usefully conceptualised as 'engagement' (Kahan & Carpenter, 2017; National Co-ordinating Centre for Public Engagement, 2017; Parkhill et al., 2013; Corner & Clarke, 2016; Hagendijk & Irwin, 2006; Rowe & Frewer, 2005; House of Lords, 2000; Irwin & Wynne, 1996; Renn et al., 1995).

There is also growing experience of using participatory approaches (especially in the global South) to overcome the social, economic and gender inequalities which undermine efforts to build engagement with the science underpinning sustainable development goals (see Escobar et al., 2017; Burns et al., 2013).

We return to the tension between information provision, dialogue and participation throughout this report, as these themes underpin our analysis of existing literature on science communication, and our recommendations for future directions.

Whilst the accumulated knowledge about communicating and engaging around environmental science topics is well-developed, the field remains far from settled, and considerable challenges remain in terms of public engagement on a number of issues in countries around the world.



Students in a biology class in Illinois. Photo: University of Springfield Illinois

Levels of scientific knowledge among the general public, if measured as simple recall of scientific facts, have remained fairly high over time (Scheufele, 2013), but only one in four Americans in 2014 could explain "what it means to study something scientifically," and only half of Americans (53%)

had a correct understanding of randomised controlled experiments (National Science Board, 2016). Surveys of European publics show that more than half of Europeans have studied science or technology (Eurobarometer, 2014a, p.4), though this figure hides some marked geographical and social differences. In the UK 71% of respondents said they had studied science but only 22% in the Czech Republic. Across the 20 European countries surveyed, 75% of those who stayed in education beyond the age of 20 had studied science. This figure was 24% for those who left school before aged 15. 64% of those who considered themselves high up the social ladder had studied science; this number was 45% for those perceiving themselves as lower down the social ladder (Eurobarometer, 2014a, p.4). Despite the high numbers of people reporting a science education in the UK, most still lack a personal connection with science, or an understanding of how scientists work (HM Government, 2017).

"Public controversies about scientific issues are no longer seen as straightforwardly attributable to a lack of knowledge."

So there remains a collective need to do more to take science to those not currently engaged in order to improve public understanding of the scientific method (Department for Innovation, Business and Skills, 2012). As this report argues though, bridging the science-public gap must follow a process that both reflects the latest social science research on effective public engagement, and remains sensitive to the rapidly changing political context in which science communication takes place.

Who communicates environmental science?

Introduction

This section maps out the environmental and sustainability science communication landscape. We recognise science communication also happens outside of these formal arenas, and that books, films and other cultural channels provide powerful ideas about science and scientists. However, this overview focuses on the formal routes of science communication. Although it is beyond the scope of this report to provide an exhaustive review of all science communication organisations, the list provided here is broadly representative of the types of activities and philosophies which define this activity. The distribution towards organisations in the global North is a reflection of what emerged from the research, rather than any deliberate filtering of the results.

Key topics in environmental and sustainability science communication

Table 1: Key topics in environmental and sustainability science communication

Table 1 maps the key topics in environmental and sustainability science relevant to communication and engagement. It provides a thematic overview of environmental issues collated from polls, surveys and journals. A 2016 Gallup poll of 30 US public environmental concerns revealed the top three to be 'pollution'; i. pollution of drinking water, ii. pollution of streams, lakes and reservoirs and iii. air pollution (McCarthy, 2016). Similar results emerge from European surveys (Eurobarometer, 2014b). Pollution, alongside conservation and species extinction, is a long-standing environmental concern which appears to be more front-of-mind for the public than climate change and related environmental issues. However, the distinction is not clear cut - many of the concerns about fracking for example appear to be connected to pollution fears, e.g. groundwater contamination (Brown et al., 2013).

Theme	The science involved	Prominent themes in communication and engagement
Climate change - Impacts	Atmospheric chemistry and climate modelling Ocean chemistry Ecology	Increased weather extremes; Warming; Ice sheet and glacier retreat; Sea level rise; Ocean acidification; Species decline/extinction
Climate change - Mitigation	Carbon sinks BECCS/Negative Emissions Alternative energy sources	Reforestation/Deforestation; Geo-engineering; Carbon capture and storage; Fracking; Wind and solar power; Nuclear energy; Air pollution; Tidal power; Hydro-electric
Biology	Agricultural Biotechnologies Ecology and ecosystem services	Genetically Modified Organisms (GMOs) Pesticides; Conservation/Species extinction; Water Pollution
Geosciences	Land surface processes	River management; Land management and zoning; Soil quality and soil conservation

A typology of science communication organisations

Our typology divides science communication organisations into six areas, presented in the six tables below

The activities carried out by the organisations identified in our review are to some extent fluid – in reality many of the organisations carry out more than one type of activity. The categorisation therefore reflects the activities to which the majority of the organisation's resources are directed. Bearing that caveat in mind, the typology provided below indicates that the field is dominated by organisations with a focus on one-way communication rather than engagement, either training scientists to be better communicators, or providing networking opportunities for science communication professionals. Importantly, our analysis revealed recent expiration of organisations due to lack of funding and lack of activity.

Table 2: Organisations and forums for training and/or supporting scientists and others to communicate science with the public

The organisations in Table 2 vary in structure, history and in the scientific specialism they address. What they have in common is the conviction that scientists themselves are in principle wel-placed to engage the public, given the necessary training, support and resources'.

Organisation name	Location
AAAS Center for Engagement with Science and Technology	US
Alan Alda Center for Communicating Science	US
Centre for Environmental and Climate Research	Sweden
Centre for Science Communication, University of Otago	New Zealand
CICERO (Centre for International Climate Research)	Norway
Climate Lab	US
Climate Nexus	US
Climate Outreach	UK
Compass Science Communications	US
ECSITE (European Network of Science Museums and Science Centres)	Europe wide
European Science Communication Institute	Europe wide
Future Earth	Europe wide
Indian Science Communication Society	India
Inter-American Network of Academies of Science	Chile
Latin American and Caribbean Network for the Popularization of Science and Technology	Latin America/Caribbean
Minerva Consulting and Communication	Europe wide
National Academy of Sciences	US
National Science Foundation	US
NERC (Natural Environment Research Council)	UK
Network for the Public Communication of Science & Technology	Global
Science Communication Network	US
Science Communication Unit at Imperial College London	UK
Singapore Society for the Advancement of Science	Singapore
Sissa Medialab	Italy
Swiss National Science Foundation	Switzerland

Table 3: Organisations communicating to and engaging the public directly with science

The activities in *Table 3* take place in a variety of settings, rather than within the walls of educational or advocacy institutions. The goal is typically to remove the barriers between science and society, by imparting the characteristics of science and the scientific attitude to the public.

Organisation name	Location
Arctic Centre Science Communications	Finland
ASTRA (Centre for Learning in Science, Technology and Health)	Denmark
British Science Association	UK
Centre for Environment Education	India
Cienca Viva	Portugal
Citizen Science Association	Global
CitizenSci	US
Coalition on the Public Understanding of Science	US
CSIRO (Commonwealth Scientific and Industrial Research Organisation)	Australia
Earth Observatory Singapore	Singapore
Francophone Association for Knowledge	Canada
Institute for Energy and Environmental Research	US
March for Science	US
Norwegian Centre for Science Education	Norway
Royal Society	UK
SciCo	Greece
Science Communication Unit Bristol	UK
Science made simple	UK
Sciencewise	UK
Scientific Saudi	Saudi Arabia
Silverhill Institute of Environmental Research and Conservation	Canada
Smithsonian Environmental Research Center	US
Syrian Researchers	Syria
The National Institute of Science Communication and Information Resources	India
The Royal Institution	UK
Urania	Germany
Vetenskap & Allmänhet	Sweden

Table 4: Building communications and engagement into the culture of science

The organisations in *Table 4* seek to foster a culture within science that recognises the importance of public communication to scientific endeavours.

Organisation name	Location
British Interactive Group	UK
Climate Communication	US
European Network of Science Centres	Belgium
European Science Events Association	Austria
National Science Communication Institute	US
Scicomm Hub	US
Science in Public Research Network	UK

Table 5: Organisations for science communication professionals

The organisations in *Table 5* identify journalists, PR consultants and other professional communicators as having a set of skills separate and beyond that which scientists can expect to acquire on top of their own specific scientific expertise. They vary significantly – for example, while Stempra seeks to connect scientists with professional communicators, the National Association of Science Writers is more akin to a trade body for science writers.

Organisation name	Location
Association of British Science Writers	UK
Association of Science Communicators	Canada
Australian Science Communicators	Australia
Canadian Science Writers' Association	Canada
Chilean Association of Science Journalists	Chile
Chinese Society for Science and Technology Journalism	China
Danish Science Journalists	Denmark
Dutch Association of Science Journalists	Holland
Earth Journalism Network	International
European Science Journalists Association	France
Finnish Association of Science Editors and Journalists	Finland
French Association of Science Journalists	France
German Association of Medical & Science Journalists	Germany
German Association of Science Writers	Germany
German Science Journalists Association	Germany
Italian Association of Science Journalists	Italy
Japanese Association of Science and Technology Journalism	Japan
Japanese Association of Science Communication	Japan
National Association of Science Writers	US
Science Communicators Association of New Zealand	New Zealand
Science Media Centre Germany	Germany
Science Media Centre NZ	New Zealand
Science Media Centre UK	UK
Society of Environmental Journalists	US
Spanish Association of Scientific Communication	Spain
Stempra	UK
Swiss Association of Scientific Journalism	Switzerland
World Federation of Science Journalists	International

Table 6: Advocates, campaigners, lobbyists, consultants and think tanks

The groups in *Table 6* range from single issue themes (e.g. Ocean Conservancy) through to groups who communicate with either the public or policymakers to influence the ends to which science is applied.

Organisation name	Location
Alliance for Accelerating Excellence in Science in Africa	Kenya
Biology Fortified	US
Campaign for Science and Engineering	UK
David Suzuki Foundation	Canada
Environmental-Economics Policy Research Unit	South Africa
Euroscience	France
Institut de France Academie des sciences	France
IVL Swedish Environmental Research Institute	Sweden
National Center for Science Education	US
Ocean Conservancy	US
Scientists for Global Responsibility	UK
Sea Change	US
Stockholm Environment Institute	Sweden
The Energy and Resources Institute	India
The National Council for Science and the Environment	US
Union of Concerned Scientists	US

Table 7: Science communication organisations that have recently ceased operating

Finally, *Table 7* identifies science communication organisations which have recently ceased operating, in most cases due to a lack of funding.

Organisation name	Location
African Federation of Science Journalists	Kenya
Brazilian Association of Science Journalism	Brazil
Connecting Science	UK
European Network of Science Communication Teachers	Europe
Graphic Science	UK
Korean Science Journalists Association	Korea
Media for Environment, Science, Health and Agriculture Association in Kenya	Kenya
Nicaraguan Academy of Sciences	Nicaragua
Science View	Greece

Science communication journals

Increasing importance is being attached to effective science communication within academia. A Web of Science search using the term 'Environmental Science Communication' for the years 2010 – 2017 identified 68,790 articles across 24 journals. Research from Borchelt (2012) and Bauer & Howard (2012) showed a marked increase in the number of science communication papers published since 2005. This growth has been described as indicating that science communication is becoming an academic discipline in its own right (Schiele et al., 2012). However, journals dedicated to science communication have low 'impact factors' (the standard metric used to rank and evaluate scientific journals). This is especially true of journals focused solely on the communication of environmental science.

Science communication scholarship has until recently been dominated by male authors from English-speaking countries in the West (Guenther & Joubert, 2017, p. 2). Whilst male Western scholars continue to dominate the field – a review in 2014 found the USA and the UK jointly accounted for 60% of science communication publications (Bucchi & Trench, 2014) – there is emerging evidence that the geographical and gender profile of the field is diversifying (Guenther & Joubert, 2017, p. 2).

Conclusions from mapping the landscape

Science communication is growing into a global and diverse discipline but our overview of the science communication landscape confirms what Trench et al. (2014) note: the field remains defined by a focus on training scientists and connecting media professionals with scientists. Public outreach through informal settings – such as museums and other civic institutions – does feature prominently. There is less evidence, however, of a concerted attempt to build institutional capacity for combining research and practice; despite being vital for creating robust and durable strategies that encourage engagement with controversial science topics. The mapping has also revealed that some key organisations are losing funding, whilst many others are voluntary and not-for-profit organisations, typically operating on very limited resources.

Our review of science communication journals reveals research is spread across many different, often low-impact journals. In addition, the studies that make up the literature in this field are fragmented, issue-specific, and anchored in different disciplines; often addressing the theme of science communication only obliquely. This situation underscores the need for institutional capacity within research centres to collate, coordinate and share research findings with communication professionals working across the domains identified in our mapping of key organisations.

"There is little evidence of a concerted attempt to build institutional capacity for combining research and practice; despite being vital for creating robust and durable strategies that encourage engagement with controversial science topics."

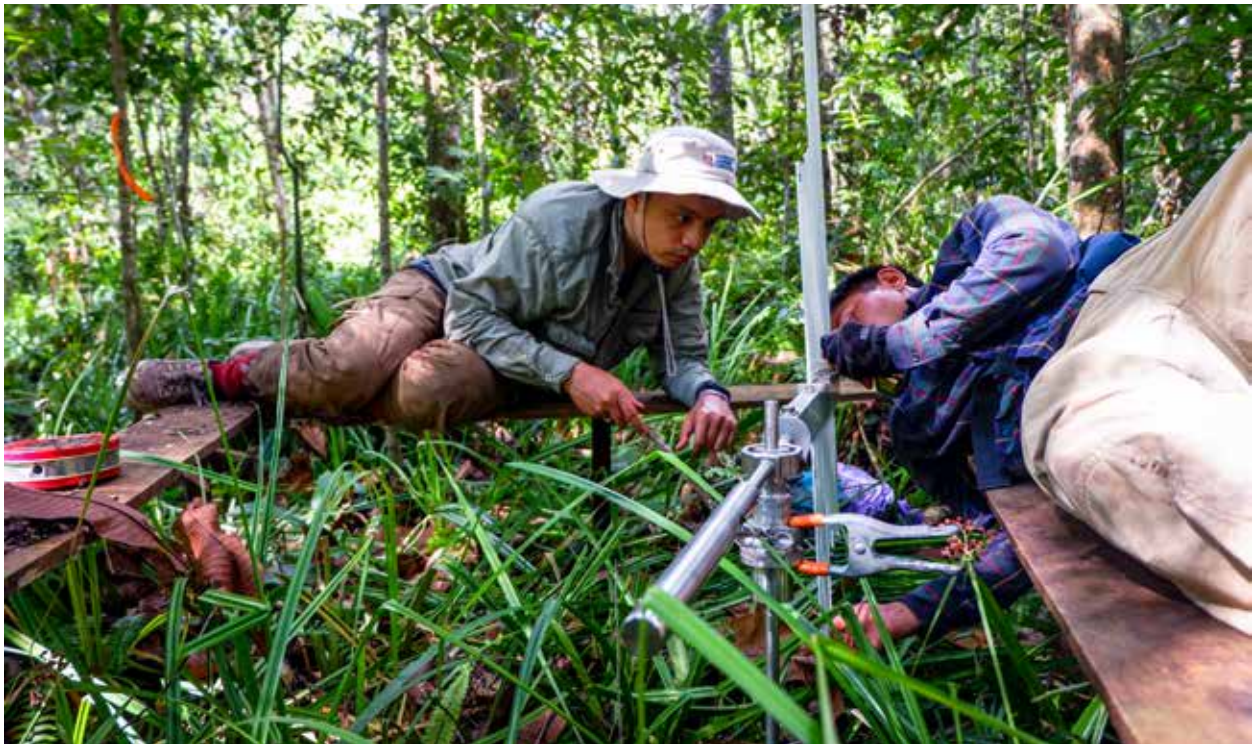
Progress in the field: a synthesis of key trends in environmental science communication research

Introduction

Having introduced some key concepts and ideas underpinning environmental science communication and engagement and mapped out the landscape in the earlier sections of this report, we provide here a succinct and concise summary of key research trends in the field. We noted earlier in the report (*page 6*) several recent and comprehensive summaries of the research base, and focus here on three research themes:

- The growing importance attributed to using frames and narratives to align messages with the needs, values and identities of different audiences.
- Challenges around communicating uncertainty and scientific consensus in climate science.
- The role of trust in building public engagement with scientific evidence.

These themes are prominent in the reports listed on *page 6* (and by extension the literature these reports summarise), and they additionally represent our judgment of what constitutes promising areas for future research. For each theme we summarise the current state of the research, and flag why these trends are likely to continue to be important going forward.



Researchers measure peat surface elevation change in Central Kalimantan, Indonesia.
Photo: Sigit Deni Sasmito/CIFOR

Values and frames

Values are 'guiding principles in the life of a person', and are distinct from beliefs or attitudes, in that they are relatively stable and fixed (Schwartz, 1992). Values, along with worldviews and political ideology, are much more fundamental in shaping views about contentious issues in environmental science than people's level of knowledge about a particular subject (Corner & Clarke, 2016). Values are the essence of identity - people identify with in-groups who share their values, and against out-groups who espouse contradictory values. This identification through shared values is the bedrock upon which specific attitudes to scientific issues such as climate change are founded (Maio, 2015). As a result, there has been growing interest in developing and testing communication 'frames' for environmental science which connect with different audience values (Corner et al., 2014).

There are many different definitions of what a 'frame' is (Nisbet, 2009), but all broadly agree that framing refers to the casting of information in a certain light to influence what people think, believe, or do. Frames are likely to influence judgments about complex science-related debates when they are relevant to an individual's existing ways of organising, thinking about, and interpreting the world (NASEM, 2017). It is important to align the framing of science messaging with the intended audience's political views when communicating environmental science because "formal knowledge constitutes only part of non-experts' appraisals of environmental risks" (Capstick et al., 2016; Slovic et al., 2007). How a message is framed, and therefore received by a particular audience, is also critical to such appraisals.

"Values, along with worldviews and political ideology, are much more fundamental in shaping views about contentious issues in environmental science than people's level of knowledge about a particular subject."

Climate change, for example, could be framed as a grave environmental risk, a public health threat, or an opportunity for innovation and economic development (NASEM, 2017). In the case of GMOs, information framed in terms of social progress and improving quality of life may fit one individual's way of thinking about the issue, while a frame that focuses on public accountability and right to know about scientific developments may appeal to another (NASEM, 2017). Campbell and Kay (2014) described the phenomenon of 'solution aversion' among US conservatives, arguing that Republicans' scepticism towards scientific knowledge about climate change and the environment is actually explained by a conflict between their ideological values and the most popular solutions to environmental problems, rather than the scientific evidence itself. This repeats findings from Kahan (2015), showing that politically conservative individuals tend to interpret expert advice on climate change more favourably when they are made aware that the possible responses to the problem do not simply include regulation and renewable energy, but also nuclear power and geo-engineering, actions that for them symbolize human resourcefulness.

Overall the science of science communication remains a developing body of knowledge (NASEM, 2017; Corner & Clarke, 2016). For example, despite the orthodoxy that positive messaging (i.e. emphasising the benefits of a particular environmental science policy or goal) is more effective than a focus on the risks, recent research has challenged this (Bernauer & McGrath, 2016; Fielding & Hornsey, 2016). One study found that, when testing positively framed messages about climate

change, including a 'counter-frame' that encompassed anti-climate change or 'denial' themes consistently undermined the impact of the positive frames (McCright et al., 2013). This suggests that even though framing-based approaches can produce measurable shifts in public views, they may be fragile or temporary (Corner & Clarke, 2016).

"There is a need to move beyond simple alterations in message framing, to a consideration of the role of stories as a way of building more sustainable and meaningful engagement."

Unsettled results such as these led one leading environmental journalist to recently dismiss the value of message-framing, suggesting that 'magic words' would not alter people's longstanding beliefs and perspectives, which are grounded in deep-rooted (and therefore unchangeable) values and worldviews (Roberts, 2016). Certainly, despite the extensive literature on differentially framing messages about environmental science for public audiences, there remains much more work to be done to improve our understanding about the longevity and efficacy of framing, in terms of meaningful changes in public engagement. But whilst it seems there are some tangible limits to the effectiveness of tweaking individual words and phrases to 'reframe' messages about environmental science, the limitations of this type of approach are not because language, words, and phrases are unimportant for public engagement. On the contrary, most attempts at linguistic reframing have arguably not gone far enough (NASEM, 2017), limiting themselves to the exchange of a small number of words in an otherwise fairly 'standard' message (Corner & Clarke, 2016).

Values and narratives

In the context of environmental science communication we define narratives as stories that describe a problem, lay out its consequences and suggest solutions (Hermville, 2016). Whilst research into framing is primarily an investigation into the content of environmental science messaging, research into narratives is largely motivated by a concern to move beyond simple alterations in message framing, to a consideration of the role of stories as a way of building more sustainable and meaningful engagement with science (Corner & Clarke, 2016). The concept of using 'narratives' for communication has become increasingly common among climate communicators (Smith et al., 2014). Most people (non-scientists) make sense of the world primarily through stories, rather than numbers and graphs (Corner & Clarke, 2016; Shaw, 2016). The use of narratives can help public audiences understand complex and abstract science issues (NASEM, 2017; Nisbet & Markowitz, 2016) and make the science easier to remember and process (Bekker et al., 2013; Dahlstrom, 2014; Kanouse et al., 2016; Winterbottom et al., 2008) relative to traditional forms of scientific communication.

Communicating science in the form of narratives appears to be more effective when those narratives use language that reflects the values of the audience (Corner et al., 2012; Kahan et al., 2010; Lord et al., 1979; Maibach et al., 2010; McCright et al., 2016; Munro & Ditto, 1997). Metaphors and analogies have a particularly important role to play in aligning messages with the values of the intended audience. Metaphors, by acting as heuristics or mental shortcuts which the audience use to evaluate complex information (NASEM, 2017; Shaw & Nerlich, 2015; Tversky & Kahneman, 1974),

makes engagement strategies more inclusive and relevant to a broader spectrum of the public (Peters et al., 2006; Sinayev & Peters, 2015) whilst also presenting the messages in a way that can help circumvent the polarisation that characterises responses to the presentation of facts and statistics (Kahan et al., 2012).

The narrative approach is not without its critics. The recent NASEM report maintains that 'despite the difficulty that numeric information poses for many people, it is sometimes the best way to promote understanding of the science, as experiments in communication about climate change, health, and the environment have demonstrated' (Budescu et al., 2009; Myers et al., 2015; Peters et al., 2014). What seems clear, however, is that a better understanding of how audiences with different value orientations engage with environmental science – through differently-framed messages and narrative-based approaches – is a promising area for future research (see the final section of this report: Gaps and opportunities for environmental science communication research).

Communicating uncertainty & consensus

Communicating the uncertainties inherent in any area of science is a major, ongoing challenge. A great deal of research has explored this topic, but because the definition of what counts as uncertainty remains contested, uncertainty is likely to remain a key focus of science communication research in the future (Landström et al., 2015; Collins & Nerlich, 2015; Hollerman & Evers, 2017). Because of the nature of scientific inquiry (where a premium is placed on exploring new areas rather than repeating established statements of fact), scientists often focus on what they don't know before emphasising points of agreement (Corner et al., 2015; NASEM, 2017). But this can give the impression that there is a lack of agreement amongst scientists on the basic facts of an issue, and can be a barrier to engagement with climate change in particular (Corner et al., 2015).

"Consensus messaging shares many characteristics of the discredited information deficit model that demands the public unquestioningly accept the authority of science."

It is often the case that uncertainty in science is misinterpreted by the public as ignorance (Freudenburg et al., 2008; Johnson & Slovic, 1995; Funtowicz & Ravetz, 1992; National Research Council, 2014; Rosa et al., 2013), and it is well-established that in many countries around the world, members of the public dramatically overestimate the uncertainty associated with climate change science and underestimate the level of scientific consensus (Lewandowsky et al., 2015; van der Linden, 2014; van der Linden et al., 2015).

In response, research has focused on methods of more effectively communicating uncertainty in climate science, with a consistent recommendation emerging around the importance of emphasising the overwhelming scientific consensus on anthropogenic climate change (van der Linden, 2014). One investigation into the effect of consensus messaging argued that when people learn that most scientists agree about climate change, they are more likely to believe that global warming is occurring and to express support for policies aimed at mitigating it (Ding et al., 2011). Another research paper concluded that communication that conveys a high degree of scientific consensus on an issue can increase people's acknowledgment of that consensus (van der Linden et al., 2015). A recent meta-analysis (Hornsey et al., 2016) of dozens of academic studies that have analysed the factors that predict belief in the reality and seriousness of climate change argued that

judgements of the scientific consensus played a major role, leading some to dub acceptance of the scientific consensus as a 'gateway belief' on which other climate-related opinions are predicated (van der Linden et al., 2015).

Despite these findings, the value of the consensus message approach has been questioned by some. Consensus messaging shares many characteristics of the discredited information deficit model that demands the public unquestioningly accept the authority of science (Pearce et al., 2015, p. 618), and is an approach that has not previously shifted people's opinions on climate change. Scientists, campaigners, and politicians have relentlessly reiterated the fact that scientists agree that humans are changing the climate for the worse - and still the disparity between scientific and public opinion remains (Kahan, 2015). Other commentaries have argued (Corner & Clarke, 2016) that claims that reiterating the consensus is an effective (and even 'non-political') tool in the climate change communication box (Maibach et al., 2014) should be treated with caution - in reality it is no more possible to pursue a non-political strategy of public engagement on climate change than it is to issue a neutral statement about abortion or GMOs (Corner & Clarke, 2016).

This doesn't mean that it is impossible to communicate about the consensus effectively – simply that the scientific consensus alone cannot overcome deep-rooted divides that stem from differences in values, worldviews, and political beliefs, or judgments about the trustworthiness (or otherwise) of those communicating the consensus. Thus, the topic of uncertainty and and consensus communication - not just for climate change but for other environmental science topics too - remains an area that is likely to be of interest for many years to come.

Trust and expertise

As current debates about 'fake news' and 'post-truth' discourse (explored in more detail in the next section of this report) show, the level of trust in scientific evidence - and in the communicators conveying the evidence - is a crucial determinant of whether a communication is received positively or dismissed. Trust is a 'key perceptual short cut' used by the public when forming opinions about complex and controversial topics (Nisbet and Markowitz, 2016, p. 3). Trust and credibility - in both the message and the messenger - define the extent to which the public will pay attention to a scientific message, the belief they will have in the message and the level of support they will give to the policy implications of the science (NASEM, 2017).

Research has found that trust is (in part) a function of the degree to which the audience identify with the messenger, and feel they hold experiences, political beliefs, and values in common (NASEM, 2017). Other key factors are the messenger's perceived level of expertise and the audience's beliefs about the messenger's motives (NASEM, 2017). Research shows consistently high levels of trust in scientists in Europe (Dunlap et al., 2016) and the US (National Science Board, 2016). The National Academy of Sciences recently reported that for information about GMOs, for example, scientists at universities and medical professionals are seen as relatively trustworthy sources of information, while industry sources are seen as least trustworthy (NASEM, 2017).

However, scientists cannot automatically assume that they are seen as trusted experts by the audience, especially when communicating scientific evidence with important policy implications. For example, confidence in scientific leaders appears to vary with gender, age, and ethnicity, being somewhat lower among women, older Americans, and nonwhites (National Science Board, 2016). Nisbet and Markowitz (2016, p. 3) report that levels of trust can vary across scientific issues and political beliefs, and as one interviewee for this report noted, there are structural economic factors that determine who benefits from scientific innovation and progress, and who is 'locked

out' of these gains, which can have a profound impact on levels of trust in scientific institutions. Politically conservative groups are more sceptical of "impact scientists," (e.g. climate scientists) who examine the environmental and health impacts of technology and industrial activities. These same groups hold greater trust in so-called "production scientists" such as engineers or chemists who produce new technologies and marketable products. In contrast political liberals tend to doubt scientific advice on nuclear energy and "fracking," technologies they view as furthering the interest of corporations rather than the public (Nisbet & Markowitz, 2016).

In summary, research to date suggests that trust in science is a nuanced and multidimensional concept, involving a complex social relationship between the audience, individual scientists, and science as an institution. A better understanding of the interplay between these different aspects of trust and how this relates to different audience perspectives looks likely to be an important focus for research in environmental science communication as debate over the 'post-truth' discourse continues.

"Trust is a 'key perceptual short cut' used by the public when forming opinions about complex and controversial topics."

Challenges 'beyond the lab' - the current social, cultural and political context for science communication

Introduction

In this section we summarise the implications of the current social, cultural and political context for science communication, and discuss three key ideas which are shaping science communication research and practice. The first of these is the growing political polarization apparent in anglophone countries. The second is an overview of the debate about the appropriate response of the scientific community to the recent shift in political language in the US and UK which has sought to denigrate the value of experts and expertise in political decision-making. The third development is the fragmentation of the media landscape, the reported rise in 'fake news' and the implications this has for environmental science communication.

Growing political polarisation

As discussed above, political orientation and ideology are amongst the most significant influences on attitudes and responses to scientific evidence (Whitmarsh & Corner, 2017). It is perhaps unsurprising then that the recent fragmentation seen in electoral democracies across the Western world (the election of Donald Trump in the US, and Britain's vote to leave the European Union being two notable examples), has been accompanied by increasing tensions around communicating environmental science (and its perceived implications for policy and society).

It is important to emphasise the significance of the political turmoil that has washed through some European nations, and particularly the US, as it is likely to have repercussions for decades to come. The UK witnessed a sharp rise in hate crimes following the Brexit referendum, attributed by the UN Committee on the Elimination of Racial Discrimination to the divisive tactics of political figures who 'created and entrenched prejudices' in society (Butler, 2016). Similar effects were observed following the US presidential election (Miller & Werner-Winslow, 2016), and even in nations where right-wing populism has not (yet) shifted the balance of power (e.g. the Netherlands, France), there is a clear sense of turbulence within and between social, ethnic and political communities. Given the established correlation between economic crisis and surging far-right support (Funke et al., 2016) some have even drawn dark parallels between the still unfolding aftermath of the 2008 financial crash and the events that followed the Great Depression a century prior. The blooming of right wing extremism in the West, combined with the more widespread – albeit less directly treacherous – allure of populism thus provides an important backdrop to public engagement on almost any issue in contemporary society. This is perhaps particularly relevant to environmental and sustainability science, support for which is strongest on the left of the political spectrum.

Many environmental science topics have implications for economic and industrial activity, posing a threat to what one Swedish analysis described as the 'masculinity of industrial modernity' (Anshelm & Hultman, 2013), and events such as the March for Science and much of the work of other advocacy groups (e.g. *Table 5* in this document) are closely linked with positively communicating about these politically contentious issues. There has been a successful campaign in the US to discredit scientific evidence which demands government regulation of industry.

Conservative think tanks have funded a countermovement against growing state intervention in economic activities from the 1960's onwards (Dunlap & McCright, 2015), with climate change as the *bête noire* of the movement (Antonio & Brulle, 2011). The conservative/liberal polarisation on environmental science is most pronounced in the US, but is also apparent in other countries with strong commitments to neoliberalism and a powerful fossil fuels industry, such as the UK, Canada and Australia (Dunlap & Jacques, 2013; Hornsey et al., 2016). The election of Donald Trump signals a wholesale shift away from environmental action in US policies, including sweeping funding cuts to the various agencies and departments – such as the Environmental Protection Agency – that comprise the US Government's environmental wing. President Trump has also promised to eliminate as much as $100 million in "wasteful climate change spending," and has begun the process of withdrawing the United States' from the United Nations' historic Paris Agreement.

To spell out why greater polarisation is a challenge for communicating effectively about environmental and sustainability science, consider the recent 'disappearance' of the climate change pages from the website of the US Environmental Protection Agency (e.g. Davenport, 2017). Because climate change is a polarised political issue, an incoming Trump administration felt able – or even obliged – to demonstrate their ideological position on climate change by literally removing references to it from official government media. As a barrier to communication, the removal of references to a topic of environmental science is hard to surpass. And the more polarised a society becomes, the more likely that expressions of ideology like this – using science as a proxy for political views – will take place. Given the important role political leadership plays in shaping public opinion on issues such as climate change (Brulle et al., 2012), these policy announcements have profound implications for the communication of scientific evidence.

The role of scientific advocacy in a 'post-truth' era

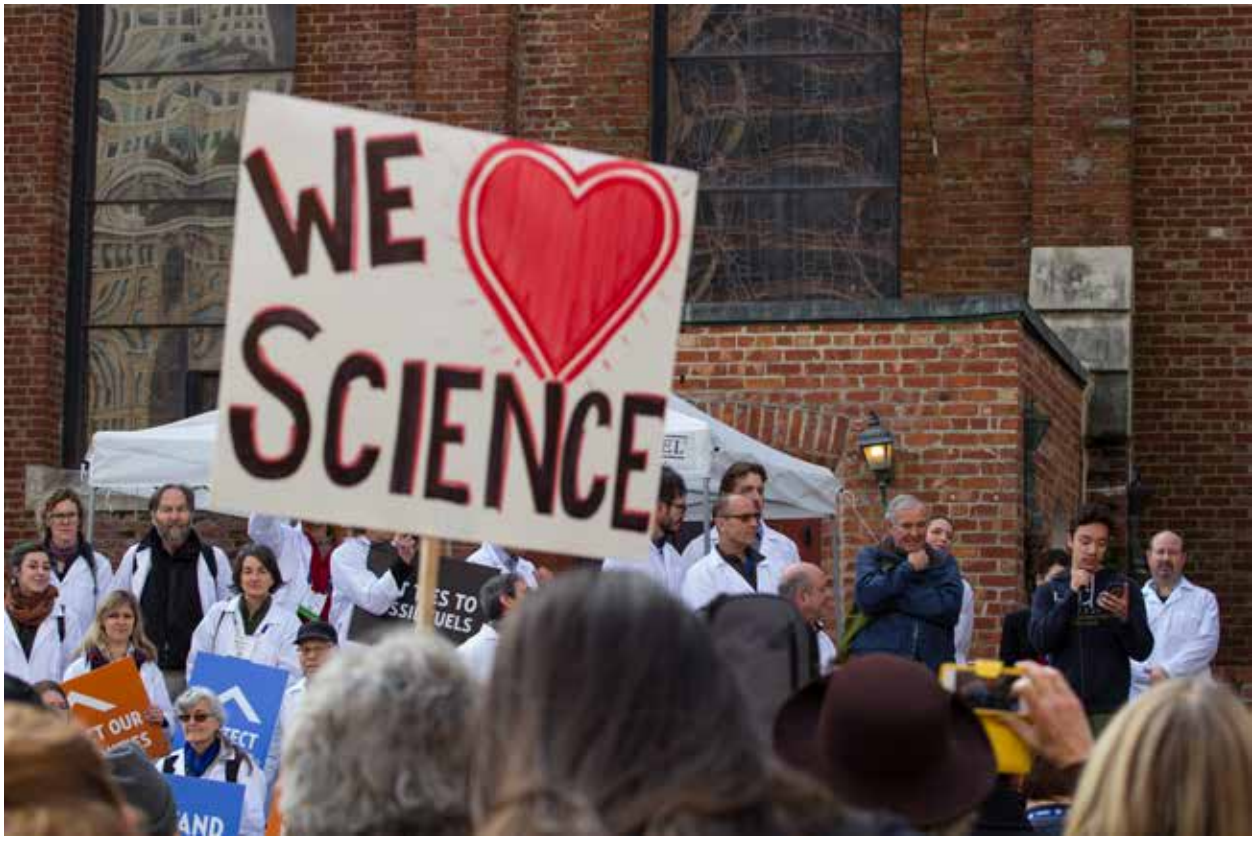
The March for Science is a vivid illustration of the shift in dynamics that President Trump's election has triggered. Although responding to the US policy context, there were nonetheless 'satellite' marches in dozens of other nations, and hundreds of cities around the world, including four in Sweden alone. Positioned as 'the first step of a global movement to defend the vital role science plays in our health, safety, economies, and governments' (Nature supports the March for Science, 2017), the fact the demonstrations were held at all (and at the scale achieved) says something important about the anxiety felt by scientists and supporters of science. As one of the experts interviewed for this report emphasised, although the US government has not historically been a major funder of science communication activities *per se*, the clear signal sent by the Trump administration – that environmental science is not worthy of public funding – is an incredibly powerful science-communication message in itself.

"The case for science needs to be made as part of an ambitious and strategic vision for Western democracies, which includes taking on issues such as widening social and economic inequality."

The marches took place within the context of a long standing debate about what is an acceptable and effective level of political engagement for scientists and what is an appropriate agenda for such activities. It has been argued scientists may harm their credibility with some audiences if they align with specific policy outcomes or one political group over another (Nisbet and Markowitz, 2016, p. 4), though some research suggests climate scientists may be able to engage in certain forms of advocacy without damaging their credibility (Kotcher et al., 2017). Surveys indicate that opinion about the March for Science is polarised between Democrats and Republicans: 61% of Democrats believe the marches will

increase public support for science, while only 22% of Republicans say the same (Funk & Rainie, 2017). There are also challenges in promoting overly simplistic messages about the ability of science alone to solve society's most pressing problems (Bell, 2017), in the absence of (necessary) social and political debate.

It has also been argued that it is not enough for scientists to campaign for a return to the pre-Trump status quo. Rather, events such as the March for Science must be part of a broader movement for social change (Nisbet, 2017). This will require a profound change in what it means to be a scientist – the case for science needs to be made as part of an ambitious and strategic vision for Western democracies, which includes taking on issues such as widening social and economic inequality. Addressing issues of inequality in society will mean addressing the inequalities within science, such as race and class (Bell, 2017). Environmental scientists are predominantly white (National Science Foundation, 2017) and tend to come from middle class families where high educational attainment is the norm (e.g. Department of Education and Professional Studies, 2014).



A Stand up for Science event in San Francisco, US. Photo: James Coleman

An overt advocacy role for scientists may not be the break with tradition it first appears. Nisbet and Markowitz cite the work of Donner (2014), who argues there is no single "correct" role for a scientist (Nisbet & Markowitz, 2016, p.5). One expert in science communication interviewed for this report suggested that any scientist who describes themselves as an 'environmental scientist' will be seen by some members of the public as already compromised and partisan by virtue of the work they do; in which case environmental scientists may well have nothing to lose by adopting an advocacy role that society has anyway accorded them. And indeed, high profile advocacy such as the March for Science is only an extension of what many scientists are already doing. For example, scientists are increasingly communicating directly to the public through various social media channels, and these communications invariably involve advocacy for some position, view, or outcome (Pearce et al., 2014). In these situations, rather than pretending to be objective, the scientist should be

'explicit about the combination of values and science that drives their views' (Schmidt, 2015). Other commentators have also questioned whether it is ever possible to communicate an issue such as climate change in an apolitical way (Rapley et al., 2014).

Accepting that scientists are inevitably advocates for their work helps humanise them. Bringing science out of its academic bubble and into the public discourse allows the people in lab coats and behind data sets to be seen and heard directly; a vital step for rebuilding trust and understanding across society (Corner & van Eck, 2014). Indeed, the March for Science website notes that science is primarily a social process, an 'enterprise carried out by people... not an abstract process that happens independent of culture and community.

'Fake news' in a changing media landscape

'Fake news' is a term that has gained traction following Donald Trump's election and the UK vote to leave the EU. It refers to a belief amongst some commentators that the growth of internet publications and social media platforms has engendered the spread of unsubstantiated rumours and speculation masquerading as facts. This is seen as a departure from the high standards of traditional mainstream journalism. This characterisation has been questioned – whilst 'fake news' undoubtedly exists it is not new nor is it only to be found on the internet (Thorrington, 2017). MMR (measles, mumps, rubella) scare stories were common in the late 1990s and early 2000s in the UK, before social media platforms such as Facebook and Twitter were being used. Media coverage reporting a link between the MMR vaccine and autism spectrum disorder led to a decline in MMR vaccination coverage in subsequent years, and an increase in measles cases in the UK and many other countries around the world (Thorrington, 2017).

Mainstream media organisations have been cutting back on science and environmental journalism over the last decade, with a consequent decline in the amount of coverage these topics receive (Whibey & Ward, 2016). At the same time, the digital sphere is becoming an increasingly relevant source of science news for the public, though figures vary by country. A 2015 poll conducted by the Associated Press and other organisations found that more than half of American adults identified internet search engines as their top source of information about science and technology, just over 40% cited Facebook, and more than 30% conversations with friends and family (Brossard, 2016). By comparison a 2014 UK survey reported that 59% of people listed television as one of their two most regular sources of information on science (with 42% specifying TV news programmes), 23% newspapers, and 15% online newspapers or news websites. The NASEM report (2017) cites research from Su et al. (2015) that indicates the move towards a reliance on online sources is especially pronounced among younger and scientifically literate audiences.

"The old model of science communication - facts and the 'truth' delivered by scientists in lab coats through the medium of large news organisations, and echoed uncritically by mainstream political parties - has come to an end."

The 2016 Digital News Report survey (Newman et al., 2016) surveyed digital news consumption across 26 countries and found 46% of all respondents were either very or extremely interested in environment news. This compares to 45% interested or very interested in politics and and 48% interested or very interested in science and technology. Topics such as sports

and arts had figures of 33% and 32% respectively (Painter et al., 2016). Out of the 26 countries surveyed interest in environment news is lowest in the UK and Scandinavian countries. Another interesting statistic to emerge from the survey was that well over half (58%) of those who identified themselves as either "very left-wing" or "fairly left-wing" are highly interested in news about the environment, compared to just 37% of those who identify as either "very right-wing" or "fairly right-wing" (Painter et al., 2016). This polarization is particularly acute in the UK and US – in the US, less than one in five (18%) of those on the right are highly interested in environment news, compared to nearly two thirds (64%) of those on the left (Painter et al., 2016).

It has been argued that anti-science ideology is endemic on-line (Ladyman & Lewandowsky, 2017) and there are surveys revealing public mistrust in the media's science coverage. In one survey only 28% of respondents thought that the statement 'Journalists check the reliability of scientific research findings before they write about them' was always or mostly true, and 71% believed that the media sensationalises science (IPSOS MORI, 2014). Given the emerging evidence that people communicate about issues such as climate change on Twitter within bubbles of like minded people (Williams et al., 2015), it seems likely social media platforms have a very real potential for deepening polarisation on environmental science issues. However, this does not necessarily mean the balanced coverage associated with legacy media is always to be welcomed. In the case of climate change, giving airtime to opposing views in order to provide 'balance' (and thus creating the impression of equally weighted opposing sides in scientific thinking) undermines public understanding of the majority or consensus view (University of Oxford, 2017). This may in part be a reflection of journalists' preferences for covering political conflicts around science, in order to tell a dramatic story (Whibey & Ward, 2016).

In summary, the old model of science communication – facts and the 'truth' delivered by scientists in lab coats through the medium of large news organisations, and echoed uncritically by mainstream political parties – has come to an end. Instead, the boundaries between the social and the scientific, between researcher and the public, are becoming increasingly porous, fuzzy and indeterminate – with all the (positive and negative) implications this has for public engagement on environmental and sustainability science.

Gaps and opportunities for environmental science communication research

Introduction

Environmental science communication, whilst having to confront a dynamic and at times unfavourable political atmosphere, would appear to have the benefit of a strong headwind of public support. People have a strong desire to know how science affects their daily lives. A UK survey reported 84% of respondents agreed that science is such a big part of our lives that we should all take an interest, and 72% agreed that it is important to know about it in their daily lives (IPSOS MORI 2014). However, the link between bodies of scientific evidence – such as those captured in Intergovernmental Panel on Climate Change (IPCC) reports – and people's daily lives or the way they think about and plan for the future, is often hazy or absent altogether (Corner & van Eck, 2014). So there are both gaps and opportunities for environmental science communication research going forward.

A better understanding of how environmental science connects with diverse audience values

Earlier in this report we reviewed ongoing and important research on values, framing and narratives. However, there has been little direct research (i.e. in the field) into how groups and social contexts (e.g. social networks, group norms, group membership, social identity) influence responses to environmental science messaging (NASEM, 2017). There are 'segmentation' models of some populations (e.g. the Six America's project; Leiserowitz et al., [2011]– which has also been extended to India; Leiserowitz et al., [2013]). The body representing the UK's research councils has recently commissioned research segmenting the UK population by their attitude to academic (though not just scientific) research, and through this process identified five main categories (RCUK, 2017). Also in the UK, Climate Outreach has been working to improve understanding of how to connect scientific evidence with different sets of values and identities, for example with centre-right audiences and faith groups (see below). But there is a dearth of understanding about how environmental science connects with diverse audience values, given the importance of values, worldviews and ideological perspectives for this process.

"There is a dearth of understanding about how environmental science connects with diverse audience values, given the importance of values, worldviews and ideological perspectives for this process."

Two UK-based examples, led by Climate Outreach, indicate the promise of taking a values-based approach to audience research on climate change. Whitmarsh and Corner (2017) developed and tested a series of 'narratives' to better engage citizens with centre-right political views. The research showed that climate justice discourses, which feature prominently in the climate change debate, did not connect well with centre-right publics. Energy saving narratives focused on conservative themes of avoiding waste, and narratives which described domestic energy production in terms of building a 'Great British Energy' system, both resonated strongly with centre-right audiences (and were well-received across the political spectrum).

Marshall et al. (2016) explored climate change messaging with five major faith groups in the UK – Buddhism, Christianity, Hinduism, Islam and Judaism – to identify not only language that works with each of the faiths, but also language that works across all of them. The project started by consulting a team of faith experts about the messages they found had been most effective in their work, and also drew on a wide range of research, educational materials and faith-based climate change statements. From this initial research, trial narratives were constructed in the form of a speech or sermon. Discussion groups (termed 'Narrative Workshops') were then held within each of the five faith groups following a testing methodology refined by Climate Outreach (Shaw & Corner, 2017). The workshops discussed values, identity and attitudes to climate change, and then appraised the trial narratives, recommending ideas around restoring 'balance' and stewardship of the Earth as narratives that could engage across faith groups.

Narrative Workshop at St John's Church in London, UK. Photo: Climate Outreach

This kind of 'applied', but carefully-designed research, is important for bridging the gap between research and practice on environmental science communication, providing evidence about how different publics make sense of the implications of environmental science, in terms familiar to their lives. But this kind of research is relatively sparse, despite the promise it holds for making progress on public engagement. Further studies in this vein – with groups from other countries and cultures targeted as a priority – would be a profitable direction for future research.

'Curiosity' about science: re-making the link between scientific literacy and public attitudes?

"Why hasn't the new 'science of science communication' achieved more?" ask Kahan and Carpenter (2017, p. 309) in a paper published at the time that this report was being written. Their answer is that too much of the research takes place in the lab, away from the real world settings where people encounter and interpret scientific evidence. There is also a tension – that surfaces regularly in debates about environmental science communication – between the notion that facts on their own are generally insufficient to engage the public effectively (i.e. the post-deficit model approach), and the undeniable centrality of facts and evidence to science communication. In a post-deficit model approach, using well-framed messages that engage diverse values, what role is there for the actual science that is, ultimately, the focus of the communication in the first place?

A reconciliatory response to these challenges is to view science not as a series of facts and figures, but as a way of understanding the world. In schools, science is taught as a series of 'answers' rather than as a method for asking questions. And, as a consequence, people seem to have different expectations about uncertainty in science, relative to 'everyday' situations where uncertainty is seen as a given (even though it is an inherent characteristic of science). One study found emphasising that 'science is a debate' as opposed to 'science is a fixed body of facts' influenced people's motivation to act on scientific messages, even if they contained uncertainty (a notorious barrier to communication – Corner & Hahn, 2009). Participants who understood that 'science is a debate' were less likely to dismiss messages containing uncertain information. So uncertainty will not always undermine the effectiveness of science communication, as long as it fits the audience's understanding of how science works. In the same way, an understanding of what science as an endeavour is may help to bridge the gap between scientific evidence and how people receive it – even in the midst of political polarisation.

One example of this is termed 'science curiosity' – an interest in science for its own sake. Research by Kahan et al. (2017) explored this concept, demonstrating that scientifically curious people tend to seek more disconfirmatory information than those low on science curiosity, and that there is less partisan polarisation on issues such as anthropogenic climate change among the science curious. Additional research (Shi et al., 2016) on scientific curiosity concluded it could be possible to improve communication about environmental science by better understanding what kinds of people are science-curious and how science curiosity related to political orientation.

Citizen science initiatives – the term for the broad sweep of activities that seek to involve members of the public directly in scientific activities (e.g. by gathering data) – may help facilitate science-curiosity and offer potential for building a more nuanced public understanding of how science arrives at answers in an ongoing process of proposing and testing hypotheses to improve prediction of real world behaviours (rather than as a static list of factual claims). A much better understanding of science-curiosity – and how to nurture it among diverse communities – would be a productive direction for future research.

Conversational approaches as a substitute for information wars

Nisbet and Markowitz (2016) note that 'efforts to debunk misinformation often have the unintended effect of backfiring, reinforcing false beliefs and fostering distrust of messengers who provide the corrections.' One possible reason the science of science communication has had limited success (Kahan & Carpenter, 2017) is that the field – natural and social science both – remains dominated by positivist philosophies that find it difficult to imagine an alternative to information transfer models.

Commenting on their reasons for not attending the March for Science (which could itself be perceived as an unrealistically simple response to a complex problem), one science communications specialist remarked "The failure of the information deficit model is a research fact but I don't know how many times we have to repeat this to scientists and show them the research" (Stone, 2017).

Whilst the potential of peer-to-peer conversation remains underexploited (Eveland & Cooper, 2013) there is growing international interest in the power of facilitated conversations as a tool for enabling a shared curiosity about (and concern for) environmental science (e.g. Shaw & Corner, 2017). It is apparent that 'if people are encouraged to informally discuss science and how it relates to problems like climate change, such conversations help promote more effortful processing of the information that people might encounter in the news or elsewhere, and this greater level of elaboration can lead to a deeper and more sophisticated understanding of complex issues' (Nisbet & Markowitz 2016, p.5).

Climate Outreach have developed a *'Climate Conversations'* framework for the Scottish Government (Shaw et al., 2016), where the target audience was the entire national population. Scotland has the world's most ambitious climate change policies (Scottish Government, 2016). One route by which the Scottish Government is seeking to build awareness is through peer led dialogues facilitated by the *'Climate Conversations'* framework. The Scottish Government intends the framework to be used by diverse groups to get the people of Scotland talking with their peers about climate change: there is no expectation or requirement that the conversation leads directly to behaviour change. A secondary purpose is to provide evidence to inform the development of climate policy by exploring public knowledge of, attitudes towards and engagement with: a) climate change b) policies to address climate change and c) the future transition to a sustainable low carbon society. The *'Climate Conversations'* framework is unusual insomuch as it provides a methodology for holding conversations about climate change that last only an hour whilst significantly reducing the level of facilitation and climate change expertise required. Importantly, it also offers a template for moving from communication to engagement at scale.

"There is growing international interest in the power of facilitated conversations as a tool for enabling a shared curiosity about (and concern for) environmental science."

These types of initiatives suggest that investment in deepening our understanding of how narrative approaches can deliver more effective environmental science communication and engagement would be an important step towards translating the potential for dialogue-based methods into reality.

From frames to narratives

Our review of the evidence on environmental science communication points to a need for improved understanding of how to use dialogue-based approaches to build deep and sustained engagement. But there is also clearly a continued need for mediated communication, where a variety of different actors communicate about science using differently framed messages.

That means more research is needed into how messages are framed and the role of narrative structures in messaging. As one of the interviewees for this report emphasised, what members of the public conceive of as 'environmental science' is broad and diverse. Climate change, for example, is typically not experienced as 'climate science', but as choices about energy infrastructure, questions about economic development in developing nations, or decisions about locating new urban infrastructure in a changing climate. These are rich, varied stories about human development. Thus it follows that rich, varied narratives about these social and political themes may hold more promise as vehicles for engaging the public on environmental science than differently 'framed' messages which are in fact not so different to standard scientific communications. We argue here that research should move from simple alterations in message framing to a deeper and more systematic consideration of the role of narratives and stories as a way of building more meaningful engagement with environmental and sustainability science. This extends to enhancing our knowledge of consensus messaging and the communication of scientific uncertainty: these themes are best explored in as realistic settings as possible, to complement and extend the lab-based knowledge base that currently exists.

The international dimension

It is clear that research into science communication has to date been focused in the global North, and the wealthy high emitting anglophone countries in particular. The need to engage global populations, to have a deeper understanding of comparisons between countries, and to work at scale will become increasingly important as the effects of climate change become increasingly intense and widespread. As a field, science communication has barely scratched the surface in terms of understanding how global publics – with very different needs, competing priorities, and aspirations – relate to environmental and sustainability sciences.

As a starting point – and based on a suggestion by one of the interviewees for this report – a regular, international survey of public opinion on contemporary environmental science topics would help to benchmark understanding and engagement across the world. Although cross-national surveys are frequently conducted, they are typically very broad in their remit (e.g. the Eurobarometer polls) and therefore do not offer much depth of understanding on any particular topic or theme. Given that many of the most pressing applications of environmental science interact powerfully with the economics of rapidly industrialising nations, ensuring that the views of members of the public within these countries on environmental and sustainability science are better understood is important.

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