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communicating environmental science

Dissemination and engagement:
finding effective ways of communicating science

The story of the relationship between scientists and society is one with many twists and turns. But through all these, the association remains a good example of a symbiotic relationship: the general public needs science and innovation to survive, or at least maintain the standards of living it is accustomed to, whilst scientists need public support and trust in order to continue their work. How eager either side is to admit this, however, is debatable and in constant flux. The need to broker this relationship has become increasingly important as science becomes more specialised and influential, widening the perceived knowledge gap between them and non specialists.

A survey commissioned in 2011 by the Department for Business, Innovation and Skills (BIS) found that the public's trust in science was in a robust state, even after episodes such as 'Climategate'. However, the public also expressed concerns with what was going on 'behind closed doors'; and whether scientists like it or not, their funding streams are ultimately at the mercy of the Government and the public they serve. It is therefore in scientists' interest, and the public's, for a more open dialogue. This issue of the environmental SCIENTIST interrogates the various attempts to strengthen this bond between specialists and non-specialists using science communication. It is a simplified, whistle-stop tour of the landscape, designed to give a snapshot of how science communication specialists and scientists engage their audiences and what the outcome achieves.

In many articles we see how science communication borrows from its subject matter and takes an evidence-based approach, gathering data to support its goals and evaluate its outcomes. In addition, we see how communication theory is fundamental to public engagement, how understanding audience needs is important to achieve successful communication.

We also explore how communication can be achieved through many media, including art, and explain how non-specialists can inform the way that we carry out science or help us shape policy using an interesting project in crowdsourcing air-quality science in Hong Kong as an example. Similarly we learn how a science centre in Bristol used public engagement techniques to help shape their award-winning sustainability policies.

Science communication is not restricted to the general public – it is important for policy-makers and practitioners too. How well those professionals understand science will dictate the effectiveness of legislation. A project at the University of the West of England has developed key issues that researchers and scientists should consider so as to engage policy-makers more effectively.

This issue of the environmental SCIENTIST provides a broad introduction to science communication and engagement. It by no means covers all science communication activities, notable omissions being the impact of new media and the Beacons for Public Engagement. What I hope comes across is that good science communication and engagement is considered and evidence based, with transparent aims and objectives. By taking this into account, being inventive with communication style and understanding our audience, good science communication can strengthen the relationship between science and society, and in the case of environmental science, expedite the move to a sustainable world.

Phil Holmes is a freelance engagement specialist and Honorary Secretary of the IES. He specialises in the communication of science through major exhibitions and installations in museums, galleries and public spaces, working on projects in (amongst others) ZSL, Royal Botanic Gardens, Kew and the Science Museum, London, and has worked in the field for over 10 years.

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Science communication in a nutshell

Phil Holmes investigates the fundamentals of how communication and science mix, and argues that the result must be an important part of every scientist's career.

Opening up research, discoveries or debates to non-specialists can be a daunting prospect for a scientist, but engaging the public with our work is an increasingly common part of our job. However, to use science communication effectively we must first unpick why it exists and what it is.

Understanding the technical and scientific marvels on which we rely is a key way that individuals can have ownership or trust in an otherwise complex world. Equally, understanding the world around us is an important part of being able to survive and grow, not just as individuals, but as communities or civilisations. More knowledgeable individuals are better able to make moral or political choices, further able to control their own destiny or make evidence-based decisions on ethical challenges posed to them[1]. In essence, an increasingly specialised technical world requires a population armed with the knowledge of how to navigate it.

The oft-cited link between science, technology and progress has its flaws, but the premise is undeniable: knowledge and innovation are linked, and a greater number of people empowered by science leads to greater prosperity[1]. Other than the economic argument, benefits to the general good are important as well. For instance, a rise in understanding of science and nature leads to improvements in areas such as public health. The benefits of science communication to the scientific community include increased support for funding and support for more extensive and ground-breaking research[1].

▼ **Table 1. Real-world examples of elements found within communication models**

Information	Sender	Channel	Noise (external to receiver)	Receiver's filters (internal to reader)	Receiver
Scientific discovery	Journalist	Newspaper	Other articles on the newspaper page Environmental conditions (hot day, busy bus etc)	Prior knowledge Emotional relationship with concept	Morning commuter
Policy	Scientist	Briefing	Pressures from above Conflicting advice	Budget reviews Career prospects	Civil servant
Scientific concept	Writer	Book	Physical comfort Distractions	Prior knowledge Preconceptions of writer Ability to deal with jargon	Bed-time reader
Scientific principle	Exhibition developer	Exhibition	Physical comfort Environmental conditions Jargon or incoherent writing	Motives for visit Group or single visitor Timetable for day	Museum visitor

COMMUNICATION IS EASY...?

Following good learning practice we should break down the phrase 'science communication' to better understand it. Firstly, communication is the transmission of a message from sender to receiver through a medium[2]. This simple model, and how well one adapts it, is the bedrock of good science communication. In reality the model is much more complicated (see **Figure 1,** overleaf). Not only is there a sender, channel and receiver but in there is also noise, which can distort or obscure messages. Applied to a real-world situation we see that not only is there noise, but the receiver has their own filter through which they receive the message.

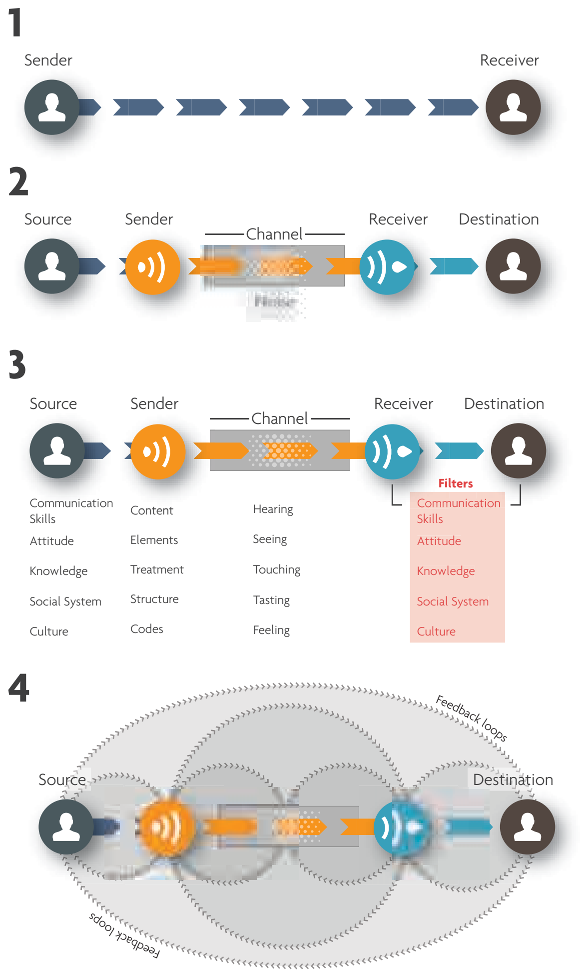
Table 1 outlines some examples of these audiences and filters. To account for filters we must build in feedback loops for the sender to modify their method or the content of the original message. The sender must also compensate for noise too. A clever piece of communication would allow the source and receiver to talk to each other, and to see what is coming through, the feedback must be reciprocal. Good communicators see the pathway of their complex message and understand its destination, then look to gain the maximum impact for their effort.

SCIENCE VERSUS NATURE

Turning to the 'science' part of 'science communication', we should remember that science itself is accurately described as a process to discover empirical truths within the observable Universe. Nature therefore is the truth we are describing or witnessing. Confusingly, as science has become increasingly specialised, the linguistic difference between science and nature has become blurred. An example of this is the language used in astronomy. For years 'natural bodies' existed in the 'ether-filled heavens'. Now, planets, pulsars, quasars and dark matter inhabit 'Space'. It seems strange to think of these 'scientific' things as natural. The distinction sounds petty, but it is important. The foundation of communication is clarity. Does the sender want people to understand how their bit of the Universe works, or how science as a method has given us that glimpse into its workings? Pulling these two apart clears your intention and gives the recipient a chance of understanding what you are saying.

In summary, science communication is a way for scientists to spread the word of their discoveries or work to non-specialists of many types, in many situations, with their own view on life. It is also becoming a way for these non-specialists to talk back.

For environmental scientists, science communication is a potentially daunting process. When we communicate our science the list of variables and conditions we use is often long and interconnected, for example one pollutant can act in different ways depending on temperature, concentrations, presence of other reactants or catalysts. It is important however that we try. Why? Individuals and communities are the cause of, solution to, and often the direct recipient of, environmental degradation. As The Natural Step reminds us, people are the fourth system condition for sustainability[4]. Without all communities understanding the natural systems in which they play a role, our goals as environmental scientists will inevitably fail. The effectiveness of environmental groups over the past 50 years has been criticised by some[5]. Perhaps this is due to the method by which they interact with non-specialists? (See **Box 1**)



▲ **Figure 1. Diagram of communication models of various complexities. (1) A simple one-way transmission. (2) Messages are encoded for transmission (i.e. interpreted by a journalist) then transmitted through a channel, decoded (by the reader) and then processed (by the reader) (Based on Shannon and Weaver, 1948[2]). (3) Filters and types of message[3]. (4) In real-world situations complex feedback loops help overcome filters and noise.**

BOX 1. COMMUNICATION AND TRUST: HARD LESSONS LEARNT

The transparency of science and the public trust in scientists are closely linked. In the past, difficult relationships between science and society have caused trust to dip. These two cases show how lack of communication and trust have hindered evidence-based debate.

The UK nuclear industry during the 1990s was facing a turning point as the first nuclear power stations were being decommissioned. The disposal of hazardous materials was to be decided by the industry-owned radioactive waste management company, Nirex, who acted very much against public opinion. Their scientists believed the waste could be safely stored underground, yet there was strong public resistance. Opposition was so strong that in 1997 Nirex was refused planning permission for a multimillion-pound repository, and the Government's long-term plans for waste disposal were suspended. Within the following years Nirex unsurprisingly turned to open public consultation in most aspects of its research and policy-making[9].

Later in the 1990s, the genetic modification (GM) of organisms became a point of conflict between the government, scientists and pressure groups. Pegged by some scientists, as holding the key to solve world poverty and starvation, large biotech firms such as Monsanto took up the technology and started to produce GM seeds. However, concern was raised, notably by groups such as Greenpeace and Friends of the Earth, about the contamination of existing crops by genetically modified organisms (GMOs) and the seemingly unnatural combinations of plant and animal DNA. The risks were perceived to be unacceptable. Meanwhile, government policy had mostly been formed before the controversy, and a furious debate exploded into the popular media. As television and print images of Greenpeace protestors destroying GM crops mixed with polemic articles about the advantages of GM, the government retracted and restructured its policies as it felt the pressures from a confused public and a potentially beneficial industry. Science as a whole suffered, as the public's faith in what scientists had to say wavered, resulting in the public image of science being degraded.

BOX 2. THE LONG RELATIONSHIP OF COMMUNICATION AND SCIENCE

The history of science can be charted not just through discovery and invention, but by communication as well. The transmission of scientific discovery before the 1450s was constrained by the very limited media available. The Gutenberg printing press began to change this by making printed books, pamphlets and notices more commonplace. Later, the dissemination of scientific information during the Enlightenment was predominantly amongst natural philosophers who began to set standards for communication within the field. However, some publications became popular with non-specialists: Robert Hooke's *Micrographia* is an example of an early popular science bestseller, with its detailed drawings of fleas, flies and leaves under the microscope. This representation of the natural world was not only inherently beautiful, it was accessible. Unfortunately as science became more sophisticated a new lexicon evolved, placing barriers between not just scientists and the public, but scientists of differing fields.

The maturation of mass media in the mid-20th century coincided with a 'golden age of science'. As advancements in home innovation, health and industry brought prosperity to the masses, the media was at first reverential of science and scientists. The outbreak of the Cold War, however, shook this relationship. As awesome destructive power, the product of scientific discovery, hung above humanity's heads, trust fell away and science was challenged as never before. Rachel Carson was one of the first popular dissenting voices; her 1962 book Silent Spring[10] unpicked the impact of pesticides in the environment. The advent of a mass media and its close relationship with the national mood resulted in a new issue for scientists. Was the press simply a mirror for scientific news, or perhaps a filter? Worse still, was it perhaps a lens through which science was being somewhat distorted? Many decades were spent with a stagnation in general scientific literacy[11].

In 1985 the Royal Society's Committee on the Public Understanding of Science (COPUS) encouraged a much higher level of scientific literacy in the UK as a whole[12]. It advocated greater media coverage of scientific discoveries, and closer relationships between scientists and journalists. Critics have argued that the 'mass' part of the media is unable to cope with the nuances of science. The relationship has been patchy, with both parties sceptical of each other's intentions.

The professionalisation of science communication through the 1990s to today has resulted in a flourish of academic theory and evidence. By measuring the effect of early science communication activity, a movement formed away from the early COPUS ideas of public understanding of science (PUS) and more towards engagement models. In these scenarios scientists and non-scientists are equal, both impacting on each other. Science communication is now diverse and moving towards a more democratic method, one of debate, engaged citizens, feedback to scientists and understanding of the way in which people learn. Science is covered on the news, in popular books written by scientists themselves, in documentaries and even in the cinema. University departments have to channel results through press offices and research funding is often dependent on engagement activity.

WHAT SCIENCE COMMUNICATION IS NOT

An attack most in the science communication sector are familiar with is the accusation that there is a dumbing-down process inherent when engaging with non-specialists. Whilst it is true that a certain degree of simplification is needed, for example stripping away extraneous information, the accusation shows a misunderstanding of why and how successful communication is achieved. Asking the question 'why?' quickly reduces the amount of information or degree of complexity needed. The receiver rarely will or needs to understand the entirety of a science topic to the same level as the source. This would necessarily involve many years of higher education and research, not possible in a workshop or poster. Therefore scientists need to communicate enough information to make the message understandable in the clearest possible way. This is not dumbing down. It is working within the limitations of the method and the audience. It is considered and effective.

Good science is based on sound evidence, and why should this not extend to its communication? Studies into the effectiveness of a variety of communication methods and various audiences' responses are readily available in the literature. Communication theory and learning theory converge effectively in science communication because of the complex demands of the message. When communicating science it is important to target each audience correctly. Discoverers, self-led learners, facilitators, contextualists, didactics, readers, listeners and doers are all possible receivers of a message. Professional science communicators target their work differently to these different audiences to get the most from their activity. (See **Box 2**)

There is an inherent belief amongst most scientists that talking to the media can be a recipe for disaster. The chance that the media will be inaccurate in their reporting or take a quote out of context is too risky for some. Interestingly, the accuracy of reporting of science stories is something that has been investigated. Science reporting by the BBC, for example, has been found to be predominantly accurate[6]. A submission to the Leveson enquiry in regards to standards of scientific reporting suggested kite-marking of stories, ensuring the proper care and research had been taken by the journalists[8], an example of scientists positively impacting the media. It has been suggested that only 23 per cent of science stories in the press are the result of active journalism, the rest originating from press departments of research institutions themselves[7]. However, scientists must be able to confidently communicate both with their press departments and the public as a whole, in order to feel secure in using these channels.

As science communication becomes increasingly mature it will be harder for scientists to embark on ad-hoc or ill-planned attempts. Indeed, many funding bodies who look for evidence of engagement and reach will seek increasingly sophisticated measures of success. In the past it may have been sufficient to build a website, write a blog or make a poster. Going forward, scientists will need to consider all elements of their engagement activity, including audience profiles, front-end and summative evaluation, feedback and consideration of the appropriateness of method and medium. This may sound like a lot of work, but the intentions are solid: it is important to embark on time- and resource-intensive activities with a degree of confidence in their impact.

SO WHAT HAVE WE LEARNT?

Science communication is a considered approach, with best and worst practices, and it is an evolving field. Well-planned and appropriate science communication can be a rewarding part of any scientist's career. Environmental scientists especially should be grasping the opportunity it affords to connect with the very people their work impacts upon. Building trust is a key part of securing a flourishing scientific community, and therefore the more open and transparent we are, the stronger non-specialists will be in supporting our work. How can we ever expect elected representatives to prioritise environmental issues without public pressure, and how can we expect the public to apply pressure without understanding the issues? Critically, how can we expect the public to understand without us talking to them, and how can we ourselves expect to successfully do that unless we understand how to?

In this issue you will get a picture of science communication and wider engagement activity, for a variety of audiences and across many subjects using an array of techniques. Despite their diversity, the professional communicators who have contributed to this all have one thing in common – their passion for science and nature, with an infectious need to let everyone know about it, something I hope you will take away and apply to your career in the future. **ES**

Phil Holmes is a freelance engagement specialist and Honorary Secretary of the IES. He specialises in the communication of science through major exhibitions and installations in museums, galleries and public spaces, working on projects in (amongst others) ZSL, Royal Botanic Gardens, Kew and the Science Museum, London, and has worked in the field for over 10 years.

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An audience-focused approach to communicating science

Good science is based on sound evidence. This is also true for good science communication, argues **Dr Helen Featherstone**.

We hear the language of engagement all around us. If we are funded by a research council, work in a publicly funded museum or gallery, or have a personal drive to listen, share and collaborate, we are expected to engage. More specifically, to "engage the public". This term covers, in the words of the NCCPE, the "myriad ways" that researchers, universities and publics interact[1].

Firstly it is worth noting that the NCCPE definition uses the word "publics", and there are multiple publics: groups of people with physical, geographical, behavioural or attitudinal similarities. Moreover, while we are all members of the general public, we are also members of multiple publics. Perhaps we belong to the parent public, or the under-25 public, or the "I love tardigrades" public. We move between our different public identities under different circumstances, depending on the context. However we conceptualise these different publics the underlying principle is that these are separate groups of people with common interests or concerns and as a result they are likely to respond similarly to any communications or engagement activities[2].

When we are considering public engagement we need to ask ourselves four questions:

- Which public?
- What is the message or content?
- To what end?
- What are the most appropriate media?

Successful engagement happens at the intersection of the answers to these questions, although the answers are not always immediately apparent and there will be an iterative process as ideas are generated, research is undertaken and boundaries drawn.

BOX 1. THE NCCPE

The National Co-ordinating Centre for Public Engagement [NCCPE] was established in 2008 as part of the £9.2m Beacons for Public Engagement initiative. The aim of the Beacons was to change the engagement culture within higher education. The NCCPE was set up to support universities to engage with the public by promoting best practice and providing a single point of contact for the whole higher education sector.

ASKING MORE QUESTIONS

The key to finding the answers to these questions is asking more questions. We must challenge each assumption we make. At the beginning, this questioning process is called front-end evaluation[3]. For example, perhaps we have spent a lifetime researching the nesting behaviour of hyacinth macaws in the tropical wetlands of Brazil and we think that by sharing our knowledge we can inspire the next generation of ecologists. During front-end evaluation we would ask ourselves: will we really inspire 13-year-olds with a lecture on the nesting behaviour of hyacinth macaws such that they go on to undertake higher education studies on biodiversity and conservation? We can turn to published research (both academic and grey) to help us on our first few rounds of iteration. This will tell us that children select their science identity long before the age of 13 (see **Figure 1**). It will also tell us that there are other forms of communication that youngsters find more memorable and rewarding than lectures, and that perhaps the nesting behaviour of a bird they may never see is not immediately relevant to their current interests.

Constructivist learning theory emphasises that new knowledge is built onto and embedded into existing constructs and knowledge. This is why it is vital to understand our audience's interests and motivations. By starting at a known point of knowledge or interest, new knowledge can be introduced and more easily retained, which is unlikely for new knowledge with no support structure. Unfortunately, this has important implications for the likely outcomes of our engagement activity: because individuals take the novel experiences and information and integrate them into their current models and knowledge, each person retains a unique interpretation of the information. This can make it challenging if a key aim of your activity is for your audience to retain and understand specific information[4].

Once we have a broad understanding of what might appeal to our target audience, we are in a position to start refining our ideas. This is where it is important to talk to some of our target audience to see if the content and format are appropriate and therefore likely to achieve the desired outcomes. This is called formative evaluation and can be immense fun. In listening to our chosen public we find out what makes them tick, we hear stories that surprise and sometimes shock us, and we generate ideas that we could never have conceived of on our own. In our nesting behaviour example, we might find that the youngsters are intrigued by the materials and skills that the birds use to build their nests, which then suggests that a craft activity might be a useful tool for stimulating discussion and learning[5].

In the audience research field we undertake front-end and formative evaluation, not only because we want to tailor the message and format, but because we know that we cannot know what will appeal, be understood or be useable[6]. Having a passion for a particular thing

▲ **Figure 1. The simple activity of seed planting is a good opportunity for children to think about what different organisms need to survive.**

or working for a particular institution alters us and it becomes almost impossible to imagine what it is like to first encounter the nesting behaviour of the hyacinth macaw or walk through the doors of a museum or gallery. This is the curse of knowledge: because we know so much and are so enthusiastic, we find it hard to understand why others do not share our passions[7].

ENVIRONMENTAL ENGAGEMENT

On the one hand, engaging publics in environmental issues follows the same guidance as all other subjects (we balance the public, content, format and outcome). On the other hand, environmental subjects have their unique challenges. Environmental issues can often be categorised as risk issues that can be distant both geographically and temporally. Risk research tells us that these types of risk issue are hard to grasp. Relating to the imminent extinction of a beetle in the Sahara is harder than if the beetle were one we encounter whilst playing in the back garden. When it was first noted that the climate was changing, the timescale for being affected by those changes was decades into the future. As human beings, we are often unclear about what we are going to do next year, and therefore find it difficult to feel concern about something 30 or 40 years into an unknown future.

On top of all this, we often want to engage publics with environmental issues because we want people to take action to mitigate the problem. It might be asking people to ride a bike to reduce their carbon footprint and thus contribute to national or international carbon reduction targets. Again, we can turn to the behaviour-change literature, which tells us that human behaviours are complex and difficult to change, and we therefore need to be specific: if we want people to ride a bike then we have to talk to them about riding bikes, rather than about wider environmental issues[8]. But not all people are interested in bike-riding so we need to find other hooks to use, such as money, health or image. Consumer research tells us that people will 'retrofit' the environmental benefit to their decision to purchase something. The argument might sound a little bit like this: "The bike was cheap and I want to get out and about a bit more. Oh, and it's good for the environment

▲ **Contact with living organisms, especially those that are unfamiliar, helps to foster care for environmental issues.**

not to drive the car all the time".

LISTENING FOR ANSWERS

During front-end and formative evaluation it will become clear that there are people who know a lot more than you do about something. You might be the expert on the nesting behaviour of the hyacinth macaw but there are also experts in education, learning, engagement and behaviour change, as well as the experts in games, media, graphic design or video production. If you decide to progress your craft activity then find someone who is an expert in using craft in educational contexts. They are likely to have challenging and inspiring ideas. You might find yourself working with a class of 30 youngsters in a forest making a human-sized macaw nest from found or recycled materials – an activity that is more fun for you and for your audience, and gives you the opportunity to listen to your audience and to share your knowledge in a way that is meaningful and relevant. You might also learn something new about yourself in the process.

So next time you are considering some public engagement, remember that it is vital to do your homework, to collaborate and to learn. It can seem daunting, but having open eyes and ears can be immensely rewarding, can challenge us about our own work, and will result in higher-quality engagement. ES

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The changing face of science communication in museums

Alex Fairhead investigates the process of putting on a major exhibition, and why listening is as important as talking.

The Natural History Museum opened in 1881 and is now home to over 70 million specimens as well as over 300 scientists and an even greater number of public engagement staff. For well over a century the museum has bridged the gap between scientific research and the public. The museum has changed a lot over this time, both in its physical structure, the way it operates and the science it communicates and how.

Many of these changes to the way science is communicated reflect much wider changes in the role of museums in society. Set up throughout the 19th century, early museums often viewed the public with a mixture of contempt and pity with museum's striving to

> *"elevate the taste and purify the morals of its visitors … providing wholesome alternatives to the seamier forms of diversions"*[1] (Watson, 2007).

The messages these museums sought to communicate were symptomatic of a place and time. Natural history museums in particular often communicated a now-obvious distortion of our place in society, constructing narratives about the superiority of Western and Caucasian societies and their dominance over and above other species and even other 'primitive' human cultures.

Whilst the buildings may have stayed the same, today's natural history museums are barely recognisable from those of the past when it comes to the science they communicate. Far from giving the message that humans transcend the rest of the natural world, they now reveal the complexity and interconnectedness of *all* species and ecosystems on our planet, and the threats that our species poses to the future of life on this planet. The ways in which the science is communicated has changed radically too. Once science was a flow of information from the learned museum professional (scientist, curator, professor) to the visitor. Now the public has a greater say, with scientists willing to explain inherent uncertainties in their work, rather than presenting all science as a series of absolute truths. Visit the Natural History Museum in London today and you'll find science communicated to a variety of audiences in many different ways, from scientific conferences and papers through to temporary exhibitions, school learning programmes and museum explainers. All of this communication is underpinned by the museum's overall vision: to advance our knowledge of the natural world, inspiring better care of our planet. For the past 14 months I have been working to deliver a part of this vision through the development of the museum's next temporary exhibition *Extinction: Not the end of the world?*

EVIDENCE-BASED AND AUDIENCE-FOCUSED

The Natural History Museum attracts nearly five million visitors a year. As well as having permanent galleries the museum puts on up to five temporary exhibitions each year. Each of these is aimed at different audiences with the intention of catering for as many of our visitors as possible. As visitors walk around one of our temporary exhibitions, whether it be *Scott's Last Journey*, *Animal Inside Out* or the upcoming *Extinction* exhibition, it may surprise them to discover the amount of research and planning that goes into an exhibition so that the science presented to them is communicated in the most approachable and understandable way (see **Figure 1**).

Typically we spend between 18 and 24 months developing exhibitions at the museum, using this time to structure our interpretative narrative, working closely with our science teams to identify stories and specimens available, and working with a variety of other internal and external stakeholders to deliver the exhibition.

For each new exhibition we consult with the particular target audience at various stages in the development of the exhibition. There are three main ways in which we consult with our audiences:

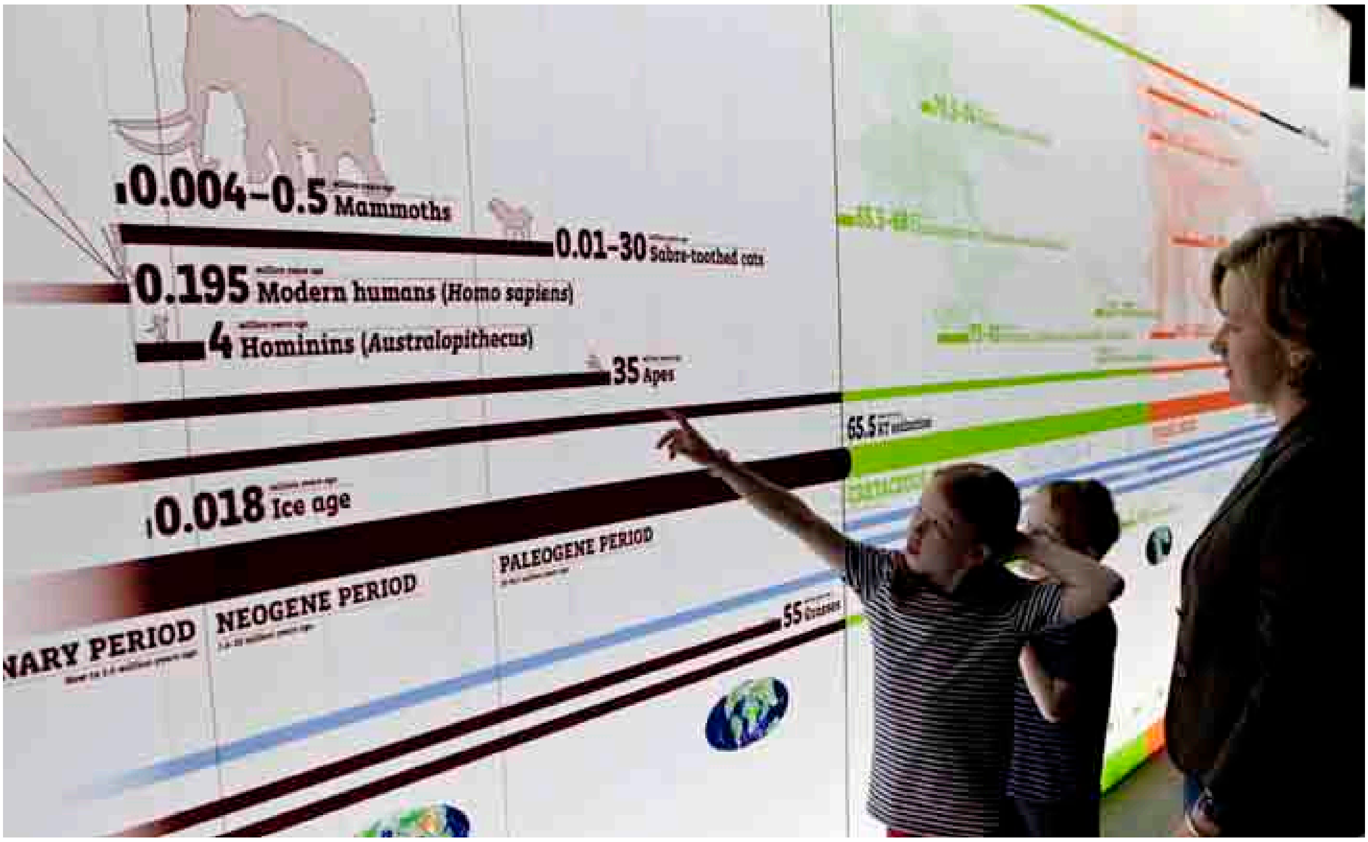
Front-end evaluation occurs during the early stages. It aims to gauge audience interest levels and prior knowledge about the subject area, and is used to set out stories, goals, communication messages, broad learning outcomes and interpretative strategies. The evaluation is usually carried out through a mixture of focus groups, online questionnaires and surveys.

Formative evaluation happens during development and production to test exhibition components, such as text, tone, graphics, interactive elements, as well as the specific communication messages and learning outcomes. It takes place during the developmental stage and it allows the findings to be incorporated into the project. Prototypes of the exhibition content are used and testing occurs in focus groups or on the museum floor.

Summative evaluation uses a variety of methods to measure the success of an exhibition or programme either during or towards the end of an exhibition's run. It aims to reveal what learning occurred and whether the exhibition or programme delivered the intended messages. This evaluation is usually based on interviews with visitors at the end of their visit to the exhibition.

COMMUNICATING SCIENCE THROUGH EXHIBITIONS

As the lead Interpretation Developer for the upcoming Extinction exhibition, my role involves developing the narrative of the exhibition, working with science colleagues to identify specimens and working with external designers to set up the exhibition. The role also involves writing the exhibition text and evaluating the exhibition throughout its development.



▲ **Figure 1. Using feedback from the evaluation processes, complex information can be presented in an accessible way.**

For *Extinction: Not the end of the world?* we ran early front-end and formative evaluations. These took the form of focus groups with the target audience for the exhibition – families with children aged 10 and over. The purpose of these focus groups was to gauge our target audience's reaction to the proposed visitor journey (the topics, stories and themes the exhibition would cover) and the manner in which they would be delivered (the tone of the text and the interpretative approach, such as the mixture of specimens, text, interactive games and films etc.).

We ran five focus groups: two with parents, one with children and two with family groups. In total around 30 people participated. The focus groups revealed the need to amend the exhibition narrative in two main ways:

Introducing more hopeful messages:

Communicating a topic such as extinction will always be difficult as it is potentially quite a depressing subject matter. This is something that came through strongly from the focus groups. Whilst there was an appreciation that we needed to focus on what extinction is and how species are threatened, and there was an interest in our doing so, it became clear that we needed to include more hopeful messages to manage the emotional journey of the exhibition. To achieve this, extinction is treated as both an end and a beginning for life, focusing on the creative force of past mass extinctions. For current extinction threats, a heavier focus was placed on conservation success stories and possible solutions to problems.

Tone and interpretive approach

With any target audience knowing what tone to use and how to pitch the exhibition text is vital. Should the text be conversational, serious, sombre, funny, delivered by a character? What makes this exhibition more challenging is that the content needs to be understandable to both adults (who are likely to have some prior knowledge on the subject) and young children. In the focus groups we tested a range of sample pieces of text, telling the tragic story of the passenger pigeon, in a range of tones – from a fact-heavy serious style through to a more colloquial, character-driven style. By far the most preferred choice was a personal style that included a wide range of facts but embellished these with a more descriptive, emotive and storytelling tone.

We have also been prototype-testing the interactive game that will feature in the exhibition: a multiplayer game where visitors adapt their species to survive mass-extinction events. We are aiming to test two prototypes of the game for up to two weeks with visitors to refine the game and ensure the key content messages are being delivered.

▲ **Figure 2. Highlighting positive messages is much more effective than focusing on loss or destruction.**

WHAT LESSONS COULD OTHERS LEARN FROM OUR AUDIENCE EVALUATIONS?

What can other science communicators, and indeed scientists, learn from the approach we have taken at the museum? I think first and foremost is the need to identify who you are trying to reach – you cannot communicate everything to everyone. Once you have clearly identified your intended audience it is very important to understand that audience, as it is all too easy to assume you know how a certain audience will think, react or what their prior knowledge and understanding on a topic will be. Once you start to dig down, common misconceptions can be revealed that you as a scientist or communicator would never have thought of. For example, whilst developing the climate science exhibition *(Atmosphere: Exploring climate science)* at the Science Museum, early front-end research revealed that most of our target audience (independent adults) believed the hole in the ozone layer (and the science behind it) were entwined with climate change (their thinking was roughly that the hole in the ozone layer allows more of the Sun's energy to reach the Earth and thereby causes climate change).

Another important lesson we have learned from our audience research is that when it comes to communicating difficult science it is best to avoid being negative and therefore depressing. For both climate change and biodiversity loss, focusing on the loss or crisis switches visitors off. Likewise using blame and guilt to deliver messages does little to engage. Instead, focusing on people's love for the natural world and the organisms it contains is a much better starting point. So too is focusing on solutions, whether they are imagining low-carbon futures or discussing conservation and how it is best practised, selling visitors hopeful messages is much more palatable and effective. These findings echo a growing body of literature on this topic, such as *Futerra's Branding Biodiversity*[6].

Another key way to communicate and engage people with science is to innovate and be unexpected. In our exhibitions we try to use as many interpretive approaches to engage our visitors as we have at our disposal – from specimens to video footage, interactive games and voting. Just because a subject has been communicated in a certain way does not necessarily mean that that is the most effective, or the only way it can be done. And ask for the input of the public: opening up a two-way dialogue, by creating participatory experiences, can offer new takes and ideas.

CHALLENGES

Understanding and evaluating visitors' reactions to our exhibitions and their content is not always easy. One of the main challenges is decoding what the public think or say in focus groups. Our research has the potential for a lot of bias: whether it consists of visitors telling us what they think we want to hear or whether sample sizes are too small, the results often have to be interpreted with caution. This is where experience comes into the situation – what visitors say they want is not always what they actually want. And by having a whole team dedicated to interpretation and evaluation we can draw

▲ **Figure 3. Creative use of space and displaying information through many media are key to keeping visitors interested.**

on many years of experience in analysing the results and finding the best ways forward. There are also the ever-present problems of lack of resources or budgets. Most science communicators would prefer more time and money to further evaluate their work.

Museums can inspire, acting as a kick-start to help people see, understand and question the world around them. Museums can offer a forum for us to communicate and talk about issues facing science. They are a symbol of a shared cultural heritage and therefore should be concerned about what we are leaving behind for future generations. But museums can only do so much. It will require a kaleidoscope of approaches, many highlighted in this journal, to begin to bridge the gap between science and the public. ES

Alex Fairhead is an Interpretation Developer at the Natural History Museum and has worked in science communication for the past four years. Prior to this he was an Intern at IES. (A.Fairhead@nhm.ac.uk)

FURTHER READING

1. Watson, S. (Ed) (2007) Museums and Their Communities. Routledge, Oxford and New York.
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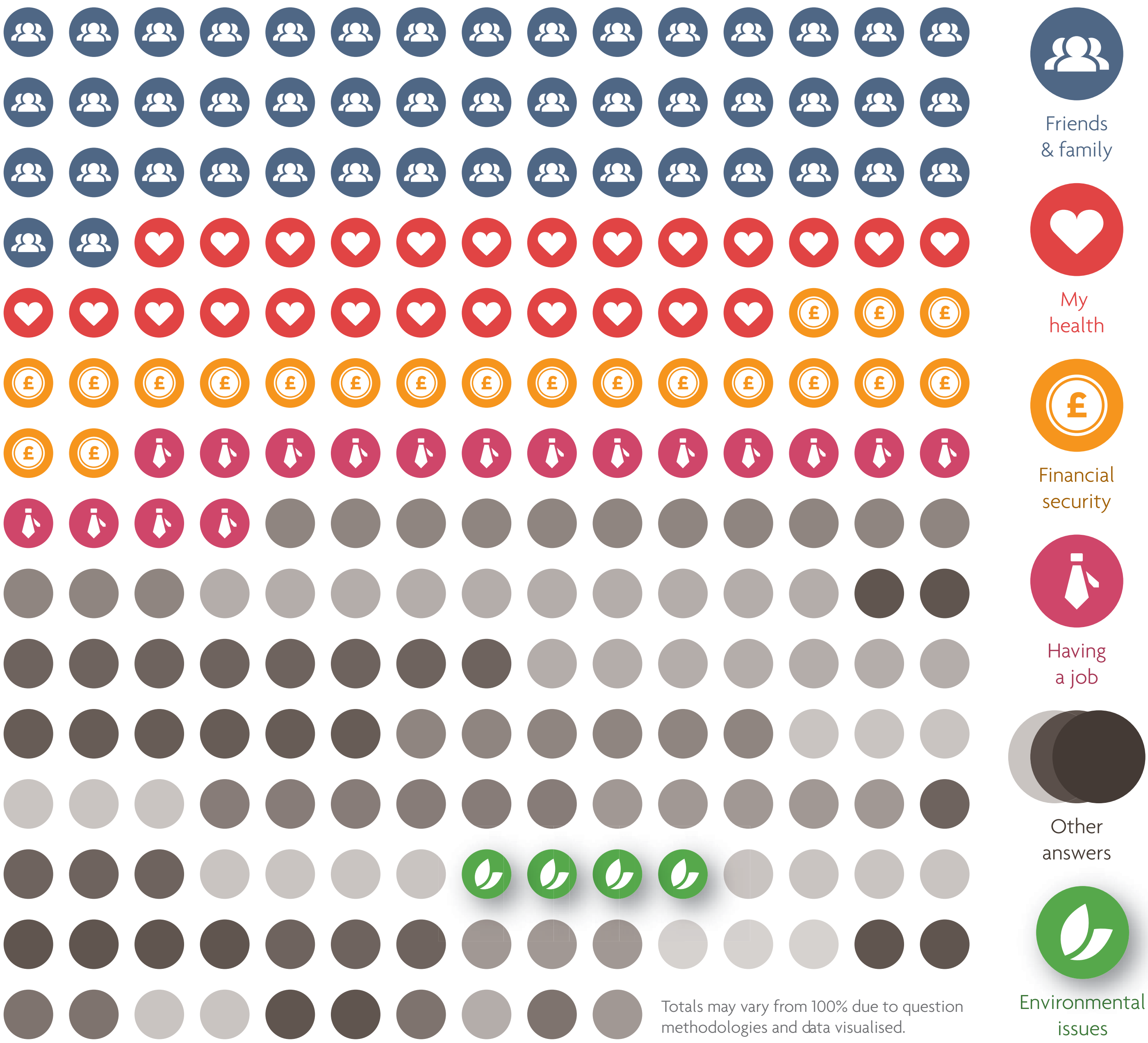
5. Science Museum. Atmosphere: exploring climate science. www.sciencemuseum.org.uk/ClimateChanging/AtmosphereGallery.aspx (Accessed 2 October 2012).
6. Futerra (2010) Branding biodiversity: The new nature message. Futerra Sustainability Communications, London. www.futerra.co.uk/downloads/Branding_Biodiversity.pdf

Public attitudes

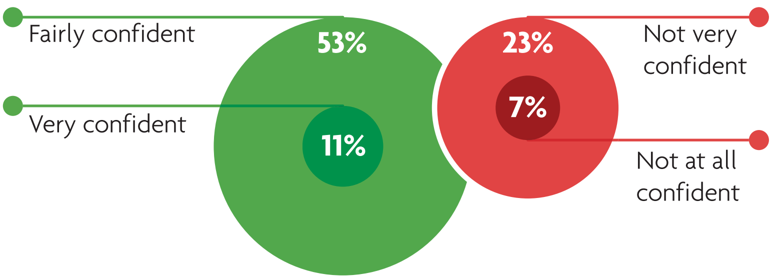
Trust and importance

Knowing your audience is a critical part of any engagement activity. Using survey results from the 'Public Attitudes to Science' survey carried out by Ipsos MORI and the Department of Business, Innovation and Skills (BIS) in 2000, 2005, 2008 and 2011, **Tom Grinsted** visually explores issues of public understanding, importance and trust in relation to the environmental sciences.

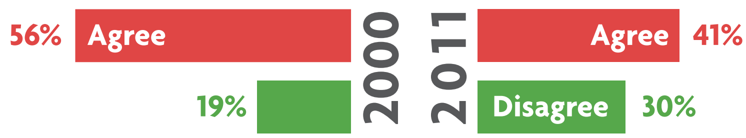
WHICH OF THESE ARE MOST IMPORTANT TO YOU PERSONALLY?



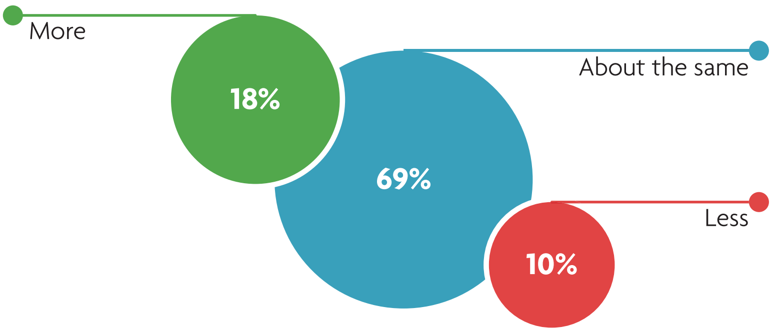
HOW CONFIDENT ARE YOU THAT UK SCIENTISTS CONSIDER THE RISKS OF NEW TECHNOLOGIES BEFORE THEY ARE USED?



"SCIENTISTS SEEM TO BE TRYING NEW THINGS WITHOUT STOPPING TO THINK ABOUT THE CONSEQUENCES."

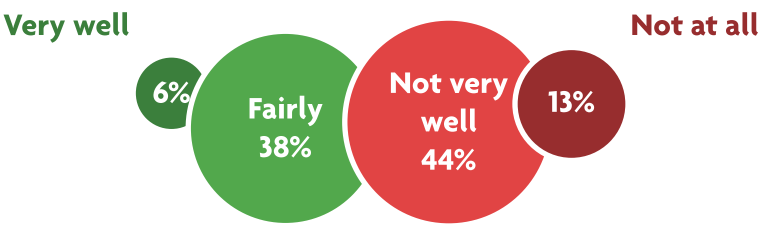


DO YOU PERSONALLY TRUST SCIENTISTS MORE, LESS, OR ABOUT THE SAME AS YOU DID FIVE YEARS AGO?

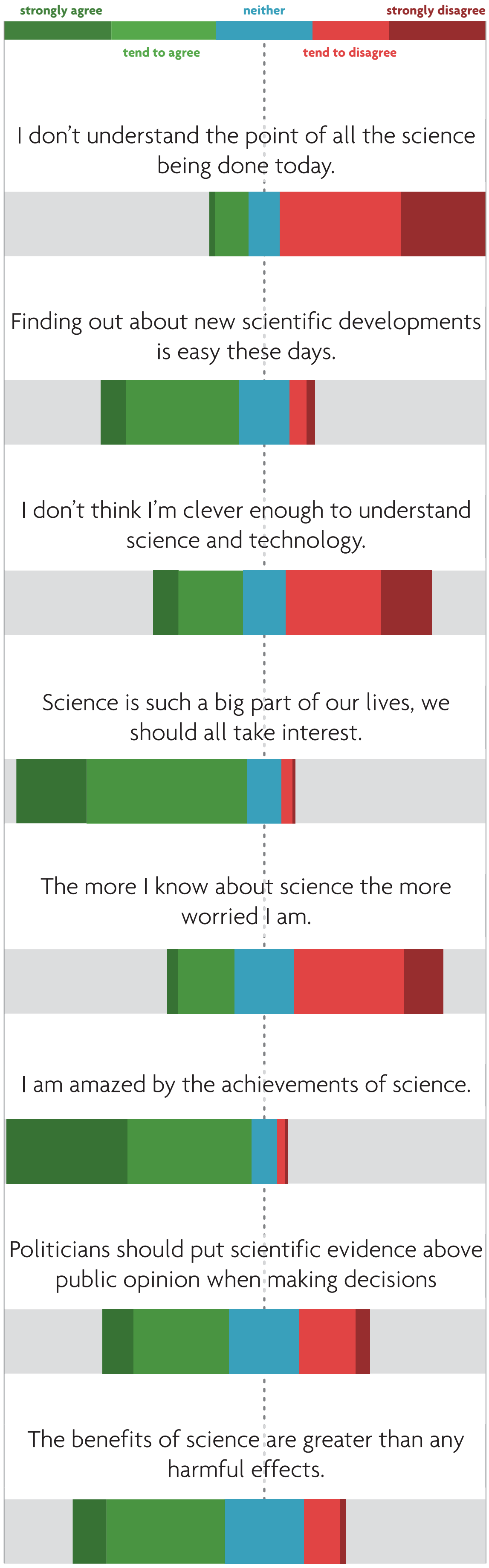


"POLITICIANS ARE TOO EASILY SWAYED BY THE MEDIA'S REACTION TO SCIENTIFIC ISSUES."

HOW WELL INFORMED DO YOU FEEL ABOUT SCIENCE?



HOW DO PEOPLE FEEL ABOUT SCIENCE TODAY?

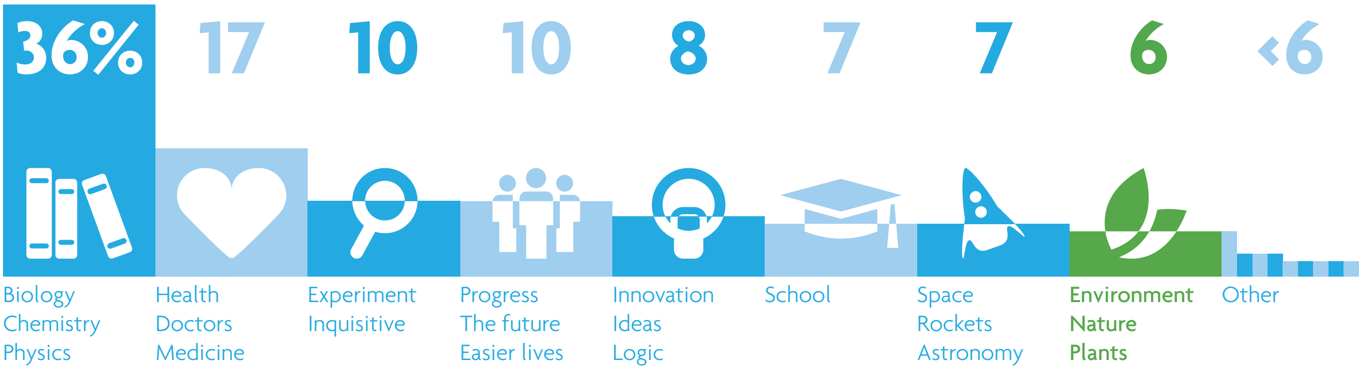


Public attitudes

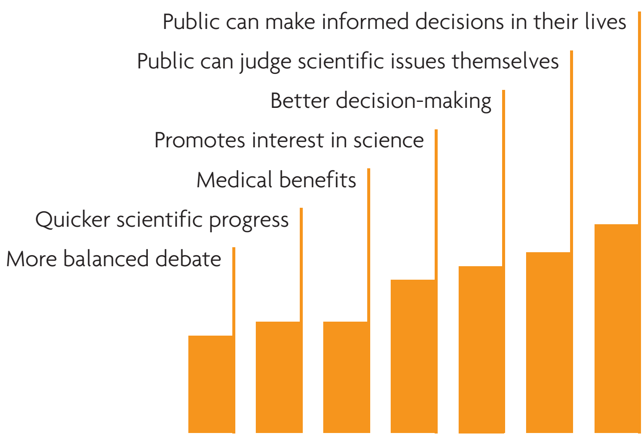
Environment and public engagement

WHAT COMES TO MIND WHEN YOU THINK ABOUT 'THE SCIENCES'?

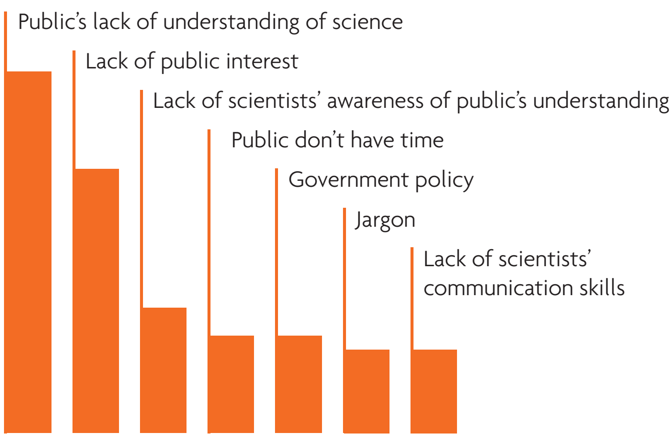
Totals may vary from 100% due to question methodologies and data visualised.



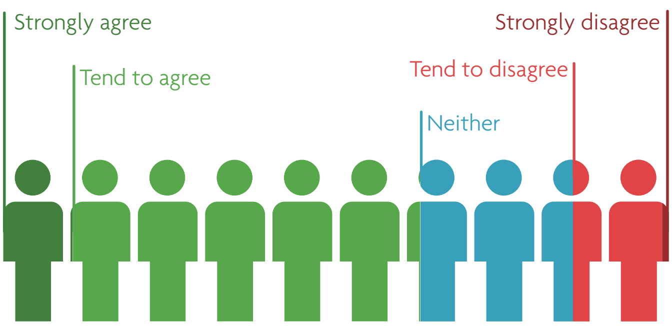
WHAT DO YOU THINK ARE THE MAIN BENEFITS TO SOCIETY FROM HAVING GREATER PUBLIC INVOLVEMENT IN DECISION-MAKING ABOUT SCIENCE?



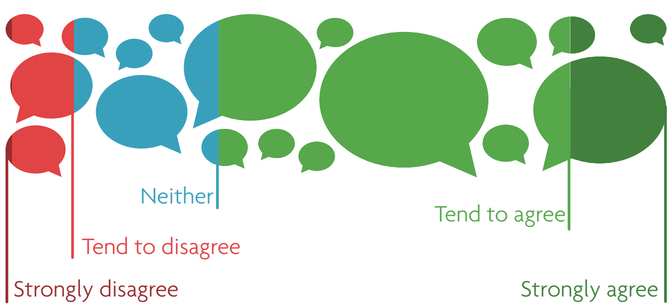
WHAT WOULD YOU SAY THE MAIN BARRIERS ARE TO HAVING GREATER PUBLIC INVOLVEMENT IN DECISION-MAKING ABOUT SCIENCE?



"SCIENTISTS PUT TOO LITTLE EFFORT INTO INFORMING THE PUBLIC ABOUT THEIR WORK."



"SCIENTISTS SHOULD SPEND MORE TIME DISCUSSING THE SOCIAL & ETHICAL IMPLICATIONS OF THEIR RESEARCH WITH THE PUBLIC."

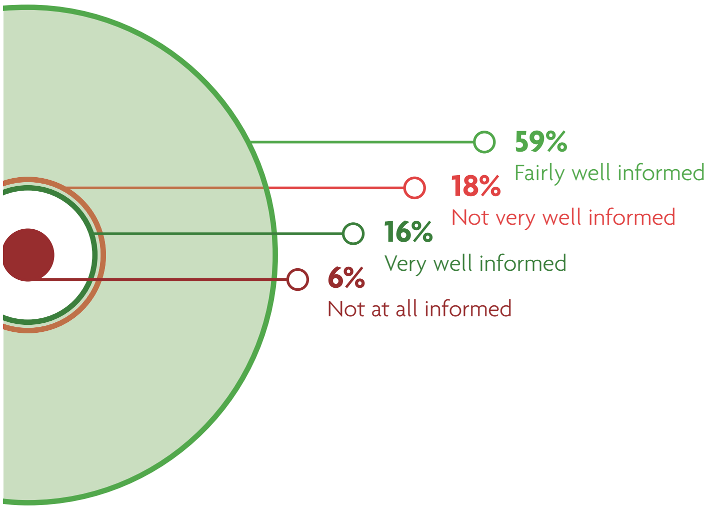


Public attitudes

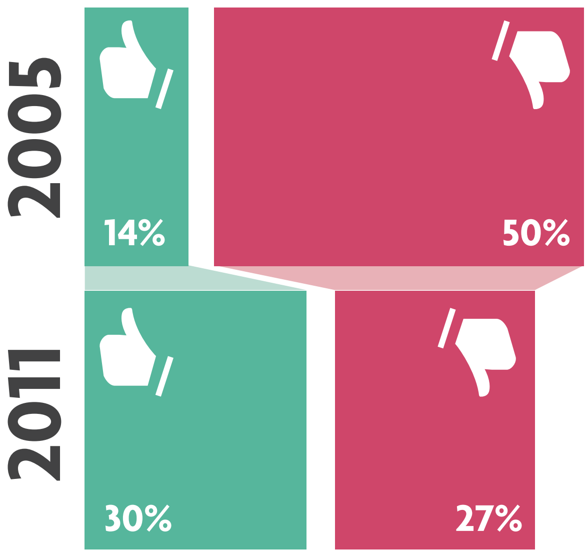
Climate change

How successful has the scientific community really been at talking to the public about climate change? How have attitudes changed over time?

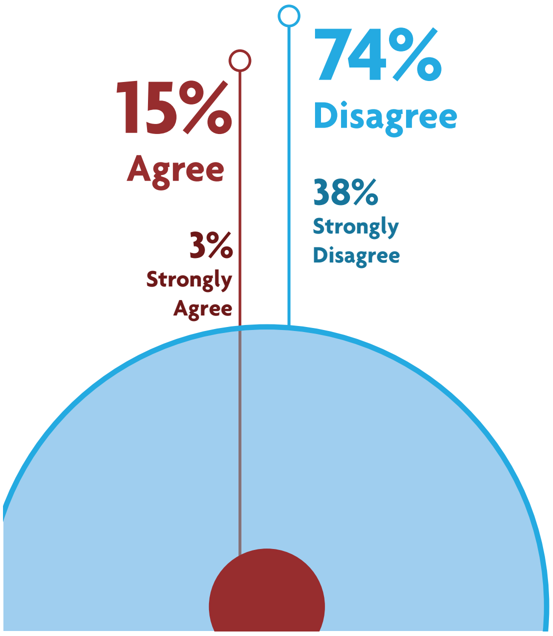
HOW WELL INFORMED DO YOU FEEL ABOUT CLIMATE CHANGE?



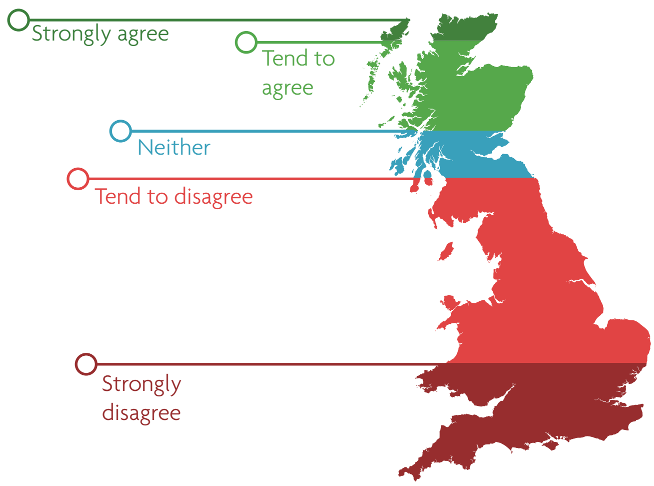
WHAT MOST CLOSELY MATCHES YOUR OPINION ABOUT CLIMATE CHANGE?



"HUMAN ACTIVITY DOES NOT HAVE A SIGNIFICANT EFFECT ON THE CLIMATE."



"THE UK IS TOO SMALL TO MAKE AN IMPACT ON CLIMATE CHANGE."



Tom Grinsted specialises in creative uses of technology. He has worked on gallery, print, mobile, and online projects for organisations including Kew, HMRC, ZSL, and the 2012 Olympics. He also works for The Guardian as a Product Manager. You can follow Tom on Twitter: @tomgrinsted. Contact him at: tom.grinsted@tooschoolforcool.co.uk

Communication through crowdsourcing: the community weather network in Hong Kong

The availability of compact and robust automatic weather stations makes it possible for members of the public to measure and monitor the weather, thus raising awareness of the weather systems that can cause natural disasters and be influenced by climate change, according to **Dr Boon-ying Lee, Kwong-Hung Tam** and **Dr Chong-wo Ong**.

This case study describes the development of the community weather network in Hong Kong, from individual automatic weather stations (AWSs) installed in a number of schools into a whole-community network offering useful weather information (temperature, relative humidity, wind speed, rainfall, solar radiation and ultraviolet radiation) for public consumption. The network now consists of about 120 members with nearly 100 AWSs set up in schools and other organizations. A Community Weather Observing Scheme (CWOS) has also been launched by the network recently to allow community members to take weather photos and make manual observations of weather and the environment via an online platform. With the accumulation of AWS data and environmental observations in the network's database, the network also holds potential for environmental applications.

THE BEGINNING

Before 2007, compact and robust AWS were already installed in several primary and secondary schools in Hong Kong under the Joint-School Meteorological Association (JSMA)[1]. The AWSs automatically reported (and still do) several weather elements at regular intervals: temperature, relative humidity, wind speed, rainfall and air pressure.

The weather information itself is primarily useful to the schools for a practical reason. Temperature and humidity readings are routinely used to set air conditioning in classrooms to combat the hot and humid weather during the hotter months of the year. To save energy, air conditioning is switched on only when the temperature and humidity exceed certain levels.

ART AND SCIENCE

In 2007, the Hong Kong Observatory (HKO; the local meteorological authority and a government department), considered it worthwhile after discussing with the JSMA to further promote the network and make the weather information it provided more widely available to the public. The aims of the change were to assist more schools and organizations in setting up AWSs and thereby promote weather education, and to provide the public with comprehensive weather information covering a wide area, with a view to enhancing public awareness of weather and climate.

Having no resources for the development work, HKO approached the Department of Applied Physics, Hong Kong Polytechnic University (PolyU) and proposed collaboration, which was promptly accepted. The outcome was the availability of a computer programmer (a software expert) and more importantly, of a number of PolyU undergraduate students to assist schools and organizations with the installation, technical adjustment and maintenance of the AWSs. While providing a learning experience for the undergraduates, the work also counts towards their community service hours. HKO's role is to provide the necessary technical advice in areas including site selection and assessment of exposure conditions, as well as the operation and maintenance of the AWSs.

▲ **Figure 1. Installing an automatic weather station (AWS) on the rooftop of a school, including a temperature sensor, a humidity sensor, a raingauge, solar and ultraviolet radiation sensors, and a small display console.**

The network was named Co-WIN, which stands for "Community Weather Information Network". It developed rapidly, and by late 2012, the number of Co-WIN members reached 118, spanning a wide spectrum of the community, from primary and secondary schools, to a care home for the elderly, the Scout Association of Hong Kong, and WWF Hong Kong.

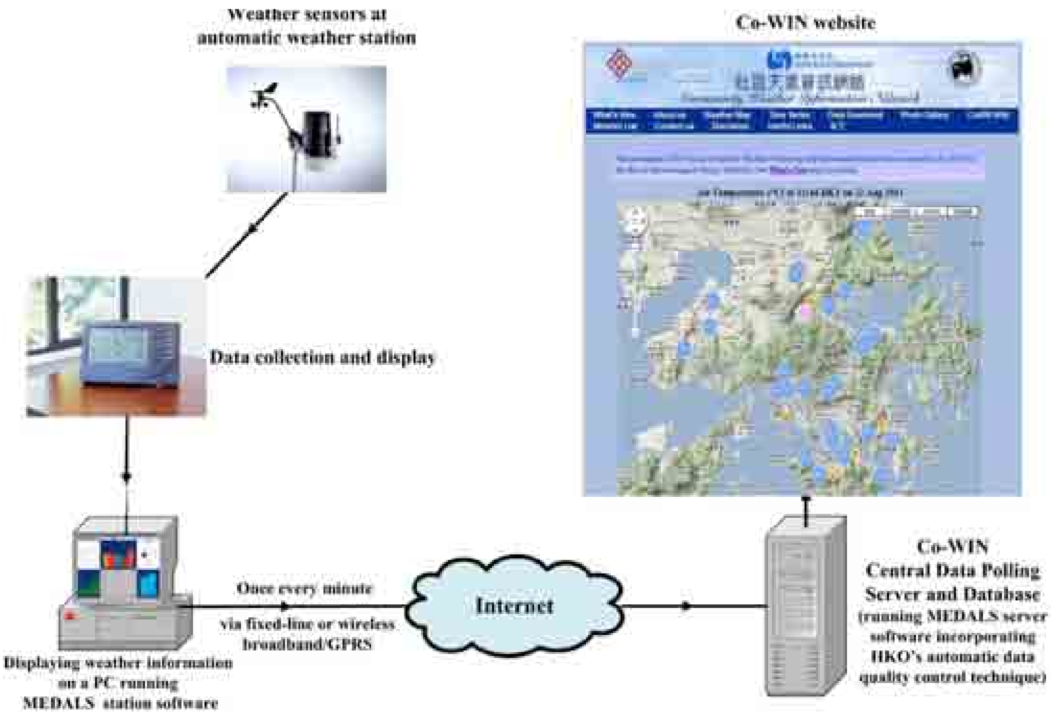
DEFINING HARM

A typical Co-WIN AWS consists of an anemometer, a temperature sensor, a humidity sensor, a raingauge, a pressure sensor and a small data display console connected to the internet via a PC. The compact and robust device is available at a cost of about HK$3000–4000 (£240–320). **Figure 1** gives an idea of its size. An optional set of solar and ultraviolet radiation sensors, costing another HK$3000–4000, is also available.

A schematic diagram illustrating the flow and processing of data is given in **Figure 2** (overleaf). The minute-by-minute weather information collected by the AWS is displayed on the console and subsequently on a PC. A piece of software called MEDALS (schematically shown in **Figure 2**) was also developed jointly by PolyU and HKO to facilitate data processing at the AWS site as well as synchronization with the rest of the network. A computer server located at the university runs MEDALS software to carry out real-time data quality assurance, and it centralizes the weather information from all members of the network. Regularly updated information from Co-WIN is available to the public on the PolyU website[2]. A sample weather map on a GIS (Geographical Information System) platform, incorporating Co-WIN AWS data and information from two registered amateur observers is shown in **Figure 3**.

DATA QUALITY

During installation, data generated by the equipment is compared with those from portable devices calibrated to measurement standards. Equipment checking is also conducted at regular intervals. Apart from instrument accuracy, the representativeness of data at any station depends on both site conditions and data availability. By far the most important factor is the site conditions, in particular the exposure of the equipment. **Figure 1** is a good illustration of a typical AWS setting in the urban environment of Hong Kong, surrounded by high-rise buildings. Strict adherence to recommendations by the World Meteorological Organization in respect of station requirements such as instrument exposure and site conditions would not be possible in many cases. However, the AWSs do provide information representative of the local conditions. For instance, urban AWSs give indications of the heat-island effect in the city area by comparison with rural AWSs.



▲ **Figure 2. Co-WIN data flow and processing (Source: Co-Win, Hong Kong Observatory.)**

Apart from equipment and data checking, the data quality at any one station is assessed by site conditions and data availability. Co-WIN member stations are assigned to one of the following categories: ordinary, advanced and fellow. Every year, each members is presented with a certificate, as recognition of their achievements over the past year. Improvement in either site conditions or data availability, or both, will bring about an upgrade to the next category after an assessment is carried out. Members who have attained a high level of data availability and participated actively in Co-WIN's activities will be assigned to the fellow category.

Based on the stations' data quality, HKO incorporates weather information from those stations in the advanced or fellow categories into its official website[3] alongside weather information from HKO's own weather station network. So far, the weather information from one Co-WIN station appears on the website.

LEARNING UNDER CO-WIN

During the implementation stage, students and teachers from schools and personnel from participating organizations are given briefings covering basic meteorology, basic knowledge regarding meteorological instrumentation, and instructions to ensure successful implementation. Participants benefit from hands-on experience gained from equipment installation, equipment checking, instrument inter-comparison as well as the testing of the communication facilities and processes. For instance, students are given the opportunity to experiment with optical polarizers

▲ **Figure 3. Display of air temperatures on the Co-WIN webpage (data from an amateur observer is shown in the pink circle). Other weather elements include: relative humidity, maximum and minimum temperatures, wind speed, air pressure, rainfall, global solar radiation, ultraviolet radiation.**

and examine their effect on the solar radiation sensor on a sunny day. Another example involves looking into differences in the data generated by an ultraviolet radiation sensor under clear, cloudy and overcast skies.

From time to time, education and experience-sharing sessions are arranged for Co-WIN members or potential members. Here, teachers and students rather than the Co-WIN organizers take centre stage. During these sessions they present their findings on a variety

▲ **Figure 4. A report to carry out urban heat island study with portable weather measuring instruments was presented by students at a Co-WIN experience-sharing session on carrying out investigative study in schools. Photo shows measurements at site being carried out.**

▲ **Figure 5a. Materials prepared by a Co-WIN member school (available in Co-WIN's Educational Resources Website) for carrying out acid rain studies.**

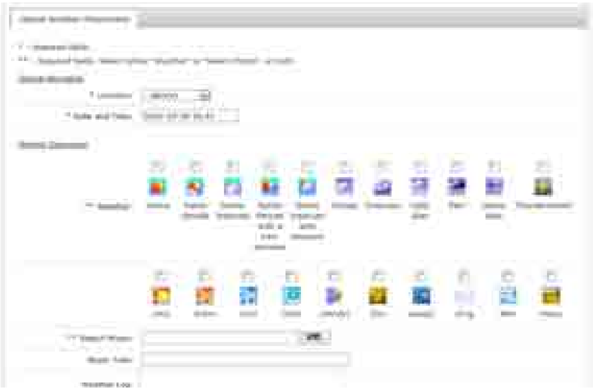
▲ **Figure 5b. Video clips available in Co-WIN's Educational Resources website to teach students how to carry out acid rain studies.**

of topics, ranging from climate studies to computation of heat stress, the heat-island effect or acid-rain monitoring. The activities encompass several academic subjects, including physics, mathematics, chemistry, geography, biology, IT and engineering. They are reported under the Educational Resources section of the Co-WIN website[4].

In view of the above, and with possible new sensors becoming available in time, it is hoped that the network has the potential for environmental applications. To encourage participation in the network as well as in the education and experience-sharing sessions under Co-WIN, visits to local nature education and meteorological facilities are arranged throughout the year. The past few years saw visits by Co-WIN participants to a nature education and astronomical centre, a weather radar station, a weather and climatological station, as well as HKO's central forecasting office.

RECOGNITION

The Co-WIN website now attracts thousands of visits every day. In 2011, Co-WIN won a certificate of merit under the Best Collaboration (Service) category in the Hong Kong Information and Communication Technology (ICT) Award. In the same year, it also won the prestigious



▲ **Figure 6. CWOS online platform for uploading weather photos and manual observations of weather and the environment.**

▲ **Figure 7a. A sample map showing weather photos uploaded to the CWOS platform.**

▲ **Figure 7b. An example of observations of weather and environmental conditions (API and RSP data obtained from a nearby monitoring station of the Environmental Protection Department of Hong Kong) shown on the CWOS website.**

2010 Vaisala Award for Weather Observation and Instrumentation from the Royal Meteorological Society in the United Kingdom.

FUTURE DEVELOPMENTS

In 2010, the Co-WIN project received attention from the annual meeting of the Typhoon Committee, organized by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) and the World Meteorological Organization (WMO). Subsequently, the Typhoon Committee made funds available for the HKO to assist in the implementation of two AWSs in developing areas of the Asia Pacific region, with a view to raising awareness.

With the involvement of the community in weather monitoring, the potential for such information to be put to good use, from avoidance of weather hazards to planning of outdoor activities and enhancing awareness of climate change, is limitless. **ES**

Dr Boon-ying Lee is former Director of the Hong Kong Observatory, which is the meteorological authority of Hong Kong, and former Permanent Representative of Hong Kong, China, with the World Meteorological Organization (WMO). Through collaboration with the Hong Kong Polytechnic University, he was instrumental in putting the Co-WIN idea into reality.

Kwong-hung Tam, Senior Scientific Officer of the Hong Kong Observatory, is responsible for Co-WIN technical matters and plays an active role in the development and further expansion of the Co-WIN project.

Dr Chung-wo Ong, Associate Professor of the Department of Applied Physics of the Hong Kong Polytechnic University, oversees the operation of the Co-WIN website and plays an important role in the development of Co-WIN and in promoting weather education in schools.

SOURCES

1. Lee, B.Y., Ginn, W.L., and Tam, K.H. (2006) Hong Kong's Enhanced Automatic Weather Station Network and its Further Outreach to Society. WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observations (TECO-2006), Geneva, Switzerland, 4–6 December 2006.
2. The official Co-WIN website "http://weather.ap.polyu.edu.hk/index.php" http://weather.ap.polyu.edu.hk/index.php
3. The official website of the Hong Kong Observatory "http://www.weather.gov.hk" www.weather.gov.hk
4. Educational Resources session within the Co-WIN website

The importance of engaging people in conservation

Dr Becky Day describes the importance of gathering support beyond the scientific community to ensure the success of conservation measures.

▲ **Figure 1. Raising awareness through road-side signs.**

What is the most dangerous and destructive species in the world? Clichéd as it may be, it is indisputably humans, responsible as we are for the sixth major extinction episode. As people are responsible, often indirectly, for the threatened status of about one-fifth of plants and animals it is logical that we should be part of the solution. It is not enough for conservationists to identify the anthropogenic causes behind a species decline – those causes must also be addressed. As Schultz said in his 2011 paper[1], "conservation is a goal that can only be achieved by changing behaviour". So what is being done to engage people in conservation? Arguably, not enough. Schultz continues to describe how conservation biology as a discipline has successfully identified and studied threats to biodiversity, but it has done less to mitigate these or cause widespread changes in human behaviour. There has been progress in the sense of awareness, concern and support for conservation in the general public.

This article highlights some of the work the Zoological Society of London (ZSL) and partners have been carrying out to engage people in vulture conservation (see **Figure 1**). ZSL is best known as the charitable organisation behind London Zoo but is also responsible for conservation in over 50 countries worldwide.

In order to achieve successful CEPA (**Box 1** overleaf) initiatives, conservationists need to step outside their traditional areas of expertise, and potentially their comfort zones, to team up with educators and social scientists. They must go out to listen to the people with the most potential to influence the future of the species they wish to save, who as well as policy-makers and governments, can often be ordinary individuals.

BOX 1. CEPA – COMMUNICATION, EDUCATION AND PUBLIC AWARENESS

There are various titles for the public dimension of conservation, none of them totally satisfactory or universally adopted. The IUCN coined the acronym CEPA and published a comprehensive toolkit to assist conservationists[2]. Despite not being widely recognised, the movement has been embraced by the zoo community as represented by this statement on the World Association of Zoos and Aquaria Website[3]:

"Article 13 of the Convention on Biological Diversity (CBD), an international treaty ratified by some 180 nations, recognises the need to create awareness and educate the public in the field of conservation. Without communication, education and public awareness (CEPA), the risk of continuing conflicts over biodiversity management, ongoing degradation and loss of ecosystems, their functions and services, will rise."

PROTECTING VULTURES

ZSL supports conservation initiatives to protect vulture populations in Pakistan, India and Nepal. Since the mid-1990s, three vulture species have suffered declines in excess of 97 per cent: the Oriental white-backed vulture (*Gyps bengalensis*), the slender-billed vulture (*G. tenuirostris*) and long-billed vultures (*G. indicus*)[4]. Unusually in conservation, the cause of this dramatic decrease is mainly due to just one factor: the treatment of cattle with the drug diclofenac (a non-steroidal anti-inflammatory drug or NSAID)[5], which causes kidney failure in birds. One dead cow contaminated with diclofenac can, due the gregarious feeding habits of vultures, cause many deaths. ZSL has worked with other international NGOs like the RSPB and in-country organisations like Bird Conservation Nepal to produce a multi-faceted response to this crisis in which CEPA is crucial.

A large part of CEPA is correctly identifying, and then really understanding, the appropriate audience. For example, whilst talking to Russian schoolchildren about the perilous status of the Amur leopard might seem worthwhile, that species could be extinct before those children are empowered to make a difference because the current wild population consists of just 30 leopards.

▲ **Figure 2. Remains of cattle carcasses put out at a vulture restaurant, with a hide in the background.**

With the vulture decline in Pakistan, India and Nepal, a key audience consists of the vets, drug suppliers and farmers who administer diclofenac to cattle; a relatively simple change in this group's behaviour can reverse the fortunes of the vulture. It is vital to understand the cultural context of this conservation issue: in Nepal, for example, as a predominately Hindu country it is illegal to kill cows, including euthanasia for welfare reasons. This means that there is a population of aged cattle who require drugs to ease their painful joints and are therefore a burden to subsistence farmers. Fortunately, there is a vulture-safe alternative to diclofenac called meloxicam, and conservationists are working with government departments to reduce barriers to its use and ensure its widespread adoption. Firstly, the conservationists had to ensure their key audience was aware of both the problem and the solution, through workshops and meetings. There was also a financial barrier to be overcome: vets and veterinary pharmacists would lose money if existing vials of diclofenac were simply taken away, so NGOs funded exchanges for meloxicam. Alongside this action, in 2006, the government of Nepal placed a ban on the manufacture and import of veterinary diclofenac[4].

Rural community groups were also enlisted to help the vultures by maintaining so-called vulture restaurants (see **Figure 2**). Ailing cattle are collected from local farmers (who receive financial compensation) and brought to centres where they see out their last days. Once they have died, their carcasses, known to be free from diclofenac, are left out for vultures. Not only does this safe meal benefit the vultures, the set-up has allowed some local communities to attract eco-tourists, who pay to watch feasting vultures from hides. Near Lumbini, the birthplace of the Buddha and therefore already on the tourist map, locals also sell produce (such as beeswax candles) to visitors and this has paid for sufficient irrigation to grow vegetable crops. One of the first vulture restaurants, near the popular Chitwan National Park, has diversified into making fertiliser from the leftover bones of carcasses and offering cultural experiences to tourists, including overnight stays in traditional houses.

Not everywhere are there such rich extrinsic incentives for living alongside vultures. In Danghadi, Kalaili District, communities are now proud to have vultures living alongside them, sometimes nesting in the trees over their houses (see **Figure 3**). This has required a significant change in attitude towards vultures, often otherwise considered an ill omen. Engagement has

▲ **Figure 3. Communities living with vultures; there is a nest in the tree just behind these ladies' homes.**

BOX 2. EVOLUTIONARILY DISTINCT AND GLOBALLY ENDANGERED

EDGE of Existence[7] is a ZSL conservation programme aimed at conserving evolutionarily distinct and globally endangered species. These include some wonderful species that are one of kind and often not receiving much conservation effort, such as the Chinese giant salamander (*Andrias davidianus*) or Attenborough's long-beaked echidna (*Zaglossus attenboroughi*). As part of this programme, promising early-career conservationists from the home range of such species are funded as EDGE Fellows. Over two years they are trained and mentored as they develop action plans for the conservation of their species, helping to build in-country capacity as well as amplifying ZSL's capacity for conservation.

At the recent international zoo educators conference, it was apparent that this is part of a wider movement within the zoo community. From tackling climate change to stopping trade in rhino horns, educators are looking at how they can influence the behaviour of zoo visitors, and use their skills to help in the human dimension of in-situ conservation. The importance of engaging people to achieve conservation is being realised and is being coupled with better techniques that go beyond increasing awareness to empowering and enabling people to actually change their behaviour. This area is ripe for expansion – people are not just the cause of problems for biodiversity but are also part of the solution.

reminded people of the vulture's cultural significance (for example with posters portraying Jatayu, the demi-god in vulture form, who rescues the kidnapped Sita in the Hindu epic *Ramayana*, see **Figure 4**) as well as the practical need for these 'dustmen' of the natural world, and has been crucial to the success of scheme. Community Forest User Groups, groups set up by the communities themselves to protect the forests they rely on, monitor the numbers of nesting vultures in what can be considered to be a type of citizen science (see **Figure 5**, overleaf).

MONITORING SUCCESS

As with any conservation intervention, it is vital to monitor it and evaluate it for successes. Measuring human behaviour can be problematic: people might not always accurately report their behaviour, and intentions often do not translate into actions. Fortunately, in this example, it is possible for conservationists to directly monitor whether people are using less diclofenac. They can check veterinary drug stores and sample the livers of cattle carcasses for traces of the drug. They can also see from nesting-site reports whether the changes in human behaviour are causing an increase in nesting vultures. Pleasingly, there are examples where this has been seen. At one nesting site in the Kailali region, 65 white-backed vulture nests were observed in 2011 compared to 33 in 2006. By 2012, Bird Conservation Nepal, partnering with government authorities, has been able to declare an area covering 122 cm^2 as diclofenac-free Provisional Vulture Safe Zones. In the future, it is hoped these areas can become the homes of captive-bred vultures, another aspect of the conservation programme, to further supplement wild vulture numbers. There is still a great deal of work to be done as vulture decline has only been slowed rather than reversed[6].

While the average visitor to a UK zoo is unlikely to direct affect vulture survival, engagement can still perform an important function as this audience can make a difference through fundraising. Each year ZSL London and Whipsnade Zoos participate in International Vulture Awareness Day in early September, allowing zoo visitors to take part in photo opportunities, raffles and crafts with all proceeds going to Pakistani, Indian and Nepali vulture projects. In 2010 over £1,500 was raised by zoo visitors, which is equivalent to about two years' salary in Nepal and therefore goes a long way to help with the running of the vulture restaurants.

EDUCATING THE CONSERVATIONISTS

Increasingly at ZSL, CEPA is being considered an integral part of conservation, and conservationists are seeking the expertise of colleagues with backgrounds in education, communication and social science. Vitally, the next generation of conservationists is being taught about the importance of considering human involvement in conservation and given some basic skills to help them with this task. In 2011 a training course was run in Nepal for a group of early-career conservationists, the EDGE Fellows (see **Box 2.**). As well as learning field techniques and data analysis, three days of the course were devoted to CEPA. Participants identified the target audience and the objectives that would need to be fulfilled for the target audience to impact species survival. They then learnt about the communication and education techniques needed to achieve this and how to evaluate the programme's success. Encouragingly, all 16 participants from around the world were already convinced of the necessity of engaging people in conservation but they

▲ **Figure 4. Examples of awareness-raising posters in community centre, including the cultural reference to Jatayu the vulture demi-god.**

sometimes lacked the correct tools or confidence to do so. They will hopefully now produce conservation action plans for their target species in which CEPA is embedded, instead of being an afterthought, and be more successful for doing so. ES

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▲ **Figure 5. The author with a Community Forest User Group; as well as environmental issues they target female education and literacy.**

Dryden Goodwin's Breathe: art, science and the invisible

Sasha Engelmann and **Alice Sharp** explore the ways in which artists are bringing the work of scientists to the attention on the public.

Art and science have always been fluid, porous entities. From the chemistry of Da Vinci's paints to the craftsmanship of the earliest microchips, the inter-permeability of art and science has driven progress in the world. Despite a modern institutional compartmentalization that distances the arts from the sciences, they revolve within a shared history characterized as much by negotiation, mutual learning, and symbiosis as by declarations of difference. But in recent years the relationship between arts and sciences has altered dramatically. Today, scientists, who are both creative and innovative in their experiments, must justify their methods to a critical and informed public. So too are artists encouraged to support their gestures and performances with formidable research. We live in an age that no longer questions the art of science and the science of art, but demands that such relationships be made even more explicit, and even more relevant to our everyday lives. This shift towards an increasingly public presentation of research and a trend toward interdisciplinary work is described by scholars as 'Mode 2' science and society.[1]

Moreover, today we are witnessing phenomena that would have been highly unlikely a few decades ago: scientists and artists actively collaborating on public projects. The scale of such projects is often breathtaking. Olafur Eliasson, an Icelandic installation artist based in Berlin, collaborated with several engineers to create his Manhattan Waterfalls Project, a series of 30-m-high waterfalls on the Lower East River between Brooklyn and Manhattan in 2010. Helen Mayer and Newton Harrison recently worked with scientist Robert Nichols to create Greenhouse Britain, a series of installations that imagined how Britain's coastal cities might be adapted to rising sea levels. And Maya Lin, in her last memorial *What is Missing?* is working with computer scientists to complete the world's first virtual database of the species, habitats and systems that are *disappearing.*[2]

In October 2012, London saw another manifestation of the increasingly public resonance of science and art: Dryden Goodwin's large-scale video installation, *Breathe*,

In much recent art, air has become the marker, not of the difference between art and life, but of the aspiration of art to trespass beyond its assigned precincts, to approach and merge into the condition of 'life'.

Steven Connor[4]

on the roof of St Thomas' Hospital. The installation was the result of collaborative research between Goodwin and lung biologist Frank Kelly of King's College London. Goodwin and Kelly met through a mutual acquaintance, Alice Sharp, who is the curator and director of Invisible Dust, a non-profit arts organization founded in 2010. Invisible Dust is actively involved in the dialogue between art and science, pairing leading contemporary artists with scientists to draw attention to air, atmosphere and climate. When Sharp invited Professor Kelly to participate in a project on air quality with Invisible Dust, Kelly welcomed the idea but had no experience working with artists. However, through initial conversations Goodwin and Kelly arrived at several ideas that would explore the visibility of the issue of air pollution in London. Sharp suggested that the two might work together to investigate and express the recent findings of Kelly's air-quality research and his contributions to the London initiative EXHALE (Exploration of Health and Lungs in the Environment), a programme undertaken by researchers and clinicians supported by the Biomedical Research Centre.

The dialogue between Goodwin and Kelly is one example in a series of art–science collaborations that Alice Sharp and Invisible Dust have catalyzed in the UK. Invisible Dust aims to generate art–science collaborations on issues that do not lend themselves to immediacy or visual clarity. The concept of invisibility is therefore at the heart of the organization's purpose. Invisible Dust sprang out of a belief that some artists are skilled in exploring the ephemeral, and do so through close observation as well as, more recently, employing new technologies such as hidden sensors or cameras. Sharp cites Joseph Amato as a thinker who articulated the importance of visual imaging of dust and small airborne particles for our perceptions of reality.[3] By pairing artists who research the transient and hidden with scientists who routinely use technologies to probe microcosmic systems, Invisible Dust aims to multiply opportunities for perceiving the invisible, and for articulating important environmental themes to the public.

INVISIBLE SERIES

Breathe is one project in a diverse series of works called *Invisible Breath,* which included Faisal Abdu'Allah's *Double Pendulum*, a film exploring the affects of air quality on high-performance athletes, and a semi-aquatic performance by HeHe (Helen Evans and Heiko Hansen) called *Is There A Horizon in the Deepwater?* that replicated the explosion of the Gulf of Mexico oil spill in the space of a swimming pool in Cambridge. But what can such novel projects offer the rigorous studies performed by scientists? How do art–science projects affect new forms of public engagement with the chemistry, physics and ecology of the invisible?

Air pollution has a famous history in London, and has been a point of engagement for artists for decades. Monet and Turner were drawn to London to paint the striking colours of the skies above Waterloo Bridge and the Houses of Parliament (the result of pollution from

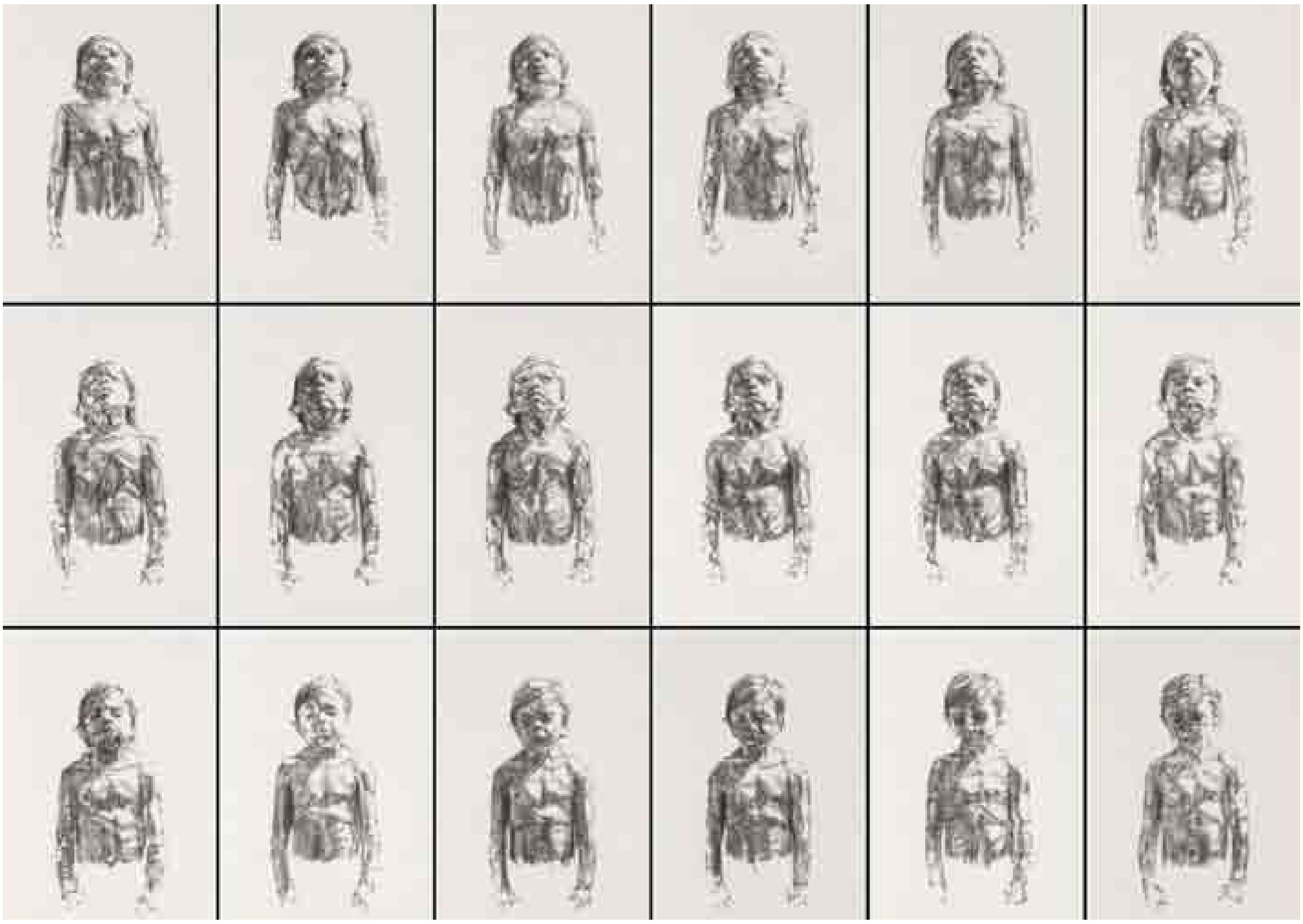
▲ **Figure 1. Using the HORIZON disaster as a way of raising awareness.**

coal fires).[4] Today, London's air is now mostly free from black smog, but as Professor Kelly and his team affirm, contains respirable particulate matter (RPM) generated by car exhausts, industrial burning and aerosols cans. Kelly is the head of the Environmental Research Group (ERG) at King's College London. The ERG monitors air quality across 33 London boroughs at over 160 sites, coordinated by the London Air Quality Network. Professor Kelly and his team have found that the smallest particles, PM^{10}s, can accumulate copper and other metals on their surfaces, with severe consequences for human lungs. Moreover, their research shows an increasingly clear connection between particles released in diesel fumes and acute respiratory damage. Such evidence is especially relevant to the work of EXHALE, as it suggests new perspectives on the causes of respiratory illness in London.

The dialogue between Kelly and Goodwin came at a time when the EXHALE team had launched a series of innovative studies with primary schoolchildren. The partnership of King's College London with the MRC–Asthma UK Centre in Allergic Mechanisms of Asthma, Barts and The London School of Medicine and Dentistry involves seven- and eight-year-old children who are believed to be most at risk from the negative effects of pollution. Children attending schools located close to main roads are studied to establish the consequences of traffic emission reduction, using comparative pollution and respiratory health data from before the introduction of the Low Emission Zone. EXHALE represents scientific research at a direct interface with the public, and is exemplary of the contexts in which researchers increasingly operate.

The creative collaboration between Goodwin and Kelly was not necessarily radical; instead, it might be seen as another step in the larger commitment to public engagement already inherent in the EXHALE project. Moreover, Professor Kelly emphasizes that the creative collaboration has potential to extend the socio-political reach of the scientific research. He feels "a new hope, as through art I have a new language, to convey important message about air pollution in our cities. Hopefully this new 'language' is understandable by everyone, including politicians, who have the power to improve our urban environments." (pers. comm.).

Public engagement with both art and science is at the core of Invisible Dust's aims. As *Breathe* took shape,

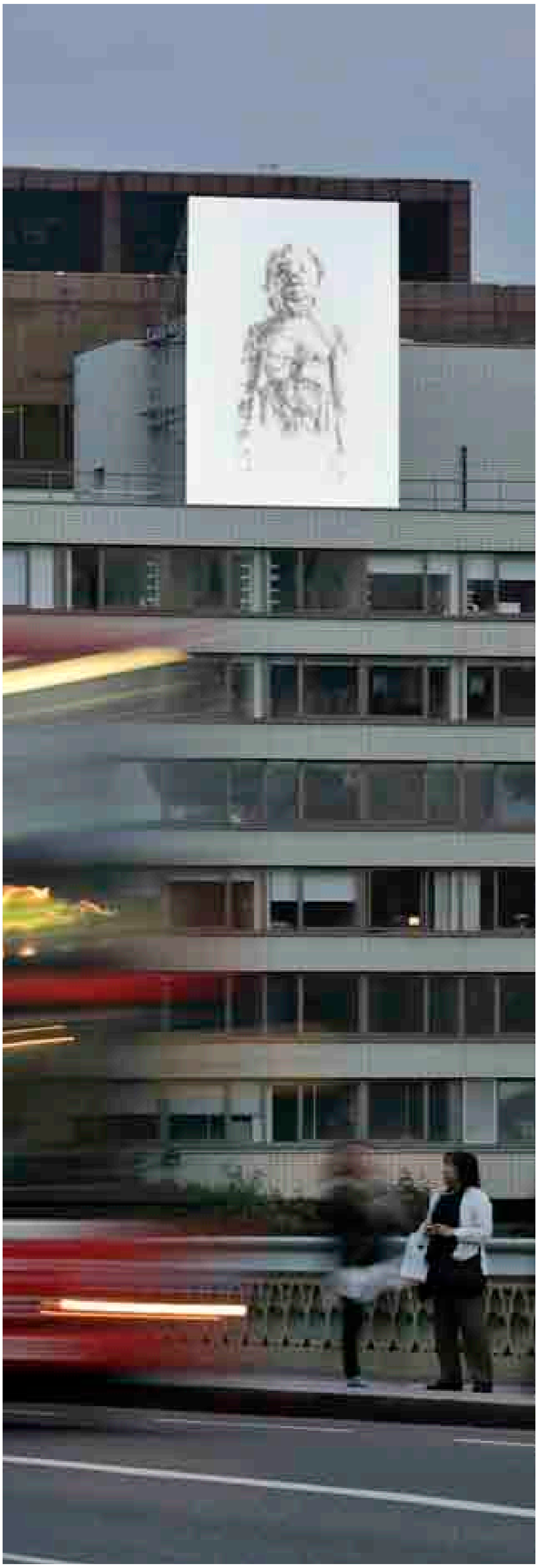


▲ **Figure 2. Breathe composite: Dryden Goodwin.**

Goodwin's and Kelly's work sparked new ideas for engaging schoolchildren with the EXHALE study: another artist, Effie Coe, joined the project and worked with the EXHALE team to develop primary school modules on atmospheric chemistry, as well as a number of art activities including ink breath drawings (shapes made when a straw is used to blow ink across paper). The initiative has been extremely successful: Effie Coe is now starting her third year with the EXHALE research group. Such projects seem to develop naturally in the space between art, science, and the public. In the last year Invisible Dust organized the View Tube Youth Project, where artist Faisal Abdu'Allah worked with scientists from the Centre for Sports Medicine and Human Performance at Brunel University to teach 15 young people from the London Borough of Newham to create their own film. At the British, Bradford and Cambridge Science Festivals in 2012, Invisible Dust designed workshop activities for children relating to breathing patterns and physiology. And in October

BOX 1. OUTCOMES OF THE BREATHE PARLIAMENT DISCUSSION

During the afternoon of 16 October 2012, Dryden Goodwin and Professor Frank Kelly discussed their recent collaboration *Breathe*, this time looking back across the river from within a committee room in the House of Commons. The *Breathe* Parliament talk was hosted by Joan Walley MP, chair of the Environmental Audit Committee together with the Parliamentary Office for Science and Technology (POST). An audience of close to 100 people shared their stories and viewpoints related to air quality in London, and many asked probing questions about the dialogue between the artist and scientist. Kelly stressed that it had been a "refreshing" experience for him to work with Goodwin, both because he learned to explain and view his own work differently, and also because he witnessed how his scientific findings were received and re-translated. Goodwin emphasized a more haptic, diagrammatic interest in the body, especially in the way breathing involves a collapsing and expanding of the human form, saying, "there is a matrix of scale in *Breathe*." Other notable comments were made by representatives of Friends of the Earth, the Clean Air Campaign, a BBC journalist and students from universities in London and elsewhere. In closing, Walley was very supportive of the art-science relationship in aiding our understanding of the environment, and she echoed Goodwin, Kelly and others in suggesting that both educational and awareness campaigns might be effectively transmitted through new social and mobile technologies.



▲ **Figure 3. Breathe in situ in London, UK.**

of this year, Invisible Dust hosted a talk at the Houses of Parliament, where the Chair of the Environmental Audit Committee Joan Walley MP discussed Breathe with Dryden Goodwin and Professor Kelly. (see **Box 1.**)

AIR MADE VISIBLE

Dryden Goodwin's involvement with Invisible Dust's wider efforts to engage the public with the issue of air quality and human health seems rather appropriate in retrospect: the task of rendering unseen relationships tangible is at the core of Goodwin's aesthetic practice. The artist's work is grounded in the experience of the city – airport terminals, underground lines and ghostly urban worlds. He has investigated the intimacy that develops between people in the urban environment through both installations and sketches, and has consistently focused on the portrait form. For *Breathe*, Goodwin created over 1,000 rough pencil sketches of his five-year-old son that frame his head, face and torso, layering them to form the semi-transparent animation. The installation is a striking new element in a heterogeneous urban space: walking along Westminster Bridge, viewers will see a luminous projection high up on the roof of St Thomas' Hospital. Activated every day at dusk, the figure of the five-year-old boy appears to fade in and out periodically. changing with the light, weather and the quality of each sunset. Breathe is unique in Goodwin's body of work: while his previous projects explored humanity in urban microcosms, the boy in his sketches faces, and even breathes with, the city of London as a whole. Moreover, this portrait is not only descriptive of a human form, but of the non-human elements that flow through it, and us, every day.

The animating gesture in Goodwin's sketches is, of course, respiration. Dryden Goodwin's drawings of the boy inhaling and exhaling convey a pneumatic energy. But their most startling quality is their ability to evoke the materiality – the heaviness – of the invisible substance. In Goodwin's sketches, air is not unremarkable, transient or still. Rather, air is an object that permeates the human figure, carrying with it the hybrid and even harmful residues of the city of London. Notably, *Breathe* will incorporate a digital component: viewers will be invited to download the *Breathe* mobile web app, from which they will be able to watch a high-resolution clip of the animated projection, access localized data on air quality provided by London Air, and upload their own photos or responses to the artwork.

In first viewing Breathe, a viewer's response might be overwhelmingly emotional. The boy appears solitary, vulnerable, even transfixed in the effort of breathing. And for some, this is precisely what art might offer a scientific subject: a degree of sensibility and feeling. One needs little evidence of the power of art to move and inspire people. Perhaps more convincing is an assertion by French philosopher Gilles Deleuze. For Deleuze, the role of art is, "to create sensations that draw humans and nonhumans into encounters with material vitality[5]." Art can create certain conditions that force humans, non-humans, and materials into immediate and unusual contact. Dryden Goodwin's scientifically informed installation is a resonant example of the way art stages an encounter between humans (viewers, pedestrians, readers), non-humans (the buildings, creatures and things of the city) and matter (air alive with organisms and particulates). The artwork brings the invisible qualities of air into a lucid encounter with humans and with city life.

Art–science projects might affect not only the emotional communication of science, but also something completely new: the production of experiences that unravel the very real but often unrecognized friction between people and the living world. Air, a substance we consider to be weightless, is rendered heavy and textured. Our lungs are re-pictured as complex systems of mediation between our bodies and the atmosphere. And the act of respiration, a subconscious rhythm, becomes symbolic of a shared fate in our air and climate. *Breathe*, then, is not just a medium for communicating a scientific

▲ **Figure 4. Ink drawing demonstrations.**

topic, nor is it purely a creative gesture. It demonstrates a new form of knowledge production through both creative and scientific engagement with the invisible, and brings the tools of both art and science to bear on an issue that belongs to neither discipline alone, but to the public of London.

FUTURE DIRECTIONS

While air quality has been a recurring theme for many of Invisible Dust projects, this area of focus will be broadened in 2013. New projects include collaborations between astronomers, deep-sea and climate scientists, and several artists including Mariele Neudecker and this year's Turner Prize nominee, Elizabeth Price. ES

Sasha Engelmann is a Marshall Scholar pursuing a post-graduate degree in Geography and the Environment at Oxford University, and a freelance writer for Invisible Dust. Sasha's interests lie at the intersection of climate change and contemporary art; her research explores the way atmosphere is rendered explicit and tangible in art-science projects.

Alice Sharp is the Director and Curator of Invisible Dust, that in 2011 won a City of London UK Sustainable City Award. As an independent curator since 1997 her previous projects include Bicycle Wheel with Gavin Turk and Ben Wilson by the Olympic Stadium and the Fourth Plinth.

Breathe is part of the 'Invisible Breath' series around air pollution and breathing with artists HeHe, Faisal Abdu'Allah and Dryden Goodwin, supported by the Wellcome Trust. Breathe is also funded by Guy's and St Thomas' Charity, and Arts Council England.

▲ **Figure 5. Breathe: Dryden Goodwin.**

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Teaching sustainability by embracing it

Chris Dunford describes ways of being 'the change you want to see' and passing that learning experience onto others.

In the At-Bristol interactive science centre on Bristol's harbourside, we engage members of the public in a broad range of sciences, from biology to astronomy, psychology to engineering and palaeontology to physics. Added to these, in the last few years we have started engaging the public in an area of science where we are the practitioners as well as being the communicators – the area of sustainability[1]. As we have developed our organisation's sustainability over the last two years we have simultaneously shared it with the public through a range of creative projects. In doing so we have linked the initiatives and innovations of our own organisation with the broader global issues of sustainability. This has allowed us to engage audiences with some of the biggest scientific issues of our age – climate change, resource management, energy, biodiversity and environmental science – from the experienced position of being an organisation working hard to monitor and improve our own environmental performance. We have found that improving our own sustainability helps us to understand the challenges involved, which complements engaging the public in what we do and helping them to put sustainability into their own lives.

Before we could launch ourselves into projects, partnerships and a specialism in engaging people around environmental issues, we first had to understand our own environmental impact as an organisation and then work to reduce it. Like many others, we found that the first and most important factor was culture change throughout the whole organisation. All our staff have been informed, motivated and facilitated to work in more sustainable ways. We formed an action group with representatives from all areas of the organisation so that every element of our operation was included, and we then set about improving our environmental and social performance. We have worked hard to reduce our environmental impact in areas such as energy, water, waste, procurement, travel and habitat, and as a science centre we have achieved this not only through changes in behaviour but by using some of the latest technologies. As a result our work has been recognised by a series of awards: a Gold Green Tourism Award, a

Silver South West Sustainable Tourism Award, being a 10:10 Campaign Success Story, and West of England Carbon Champions in both 2011 and 2012.

USING LESS ENERGY

Arguably the greatest environmental impact of our operation is through the energy we use, and so energy reduction was one of our key priorities. By monitoring our energy usage in great detail and introducing and testing measures to reduce it, we managed a 20 per cent energy reduction in 24 months, saving 180 tCO_2. This was achieved by a range of simple and inexpensive behaviour changes combined with using some of the most cutting-edge technology available. Our building contains the only phase-change tank in the UK; this device acts like a giant battery, storing energy from air-source heat pumps that run only on night electricity. The contents of the tank are distributed around the building by a network of water-source heat pumps, and this network means that the building has the ability to move heat from where it is not wanted to where it is wanted, rather than actively heating and cooling different parts of the building simultaneously. The result is an incredibly energy-efficient building that does not burn any fuel onsite. There is also a large 50-kW photovoltaic array on our roof generating 48 MWh of electricity per year from the sun.

We have found that of all the areas of our sustainability work it is energy and the science behind our building's innovative technologies that have given us the most scope for engaging the public, and from that context to speak to them about the larger issues of energy and climate. The simplest example of this is running behind-the-scenes tours of our building's low-energy equipment. These tours originally began for local businesses and energy professionals but we soon found that there was strong demand for them from the general public. The tours now run for visitors, school groups, university students, corporate groups throughout the year and as part of Bristol's Big Green Week and Bristol Doors Open Day. They receive excellent feedback and have featured in the press and in science television shows. What has been most surprising, and exciting, is the appetite of audiences to learn about green technologies by seeing them in situ and in real use.

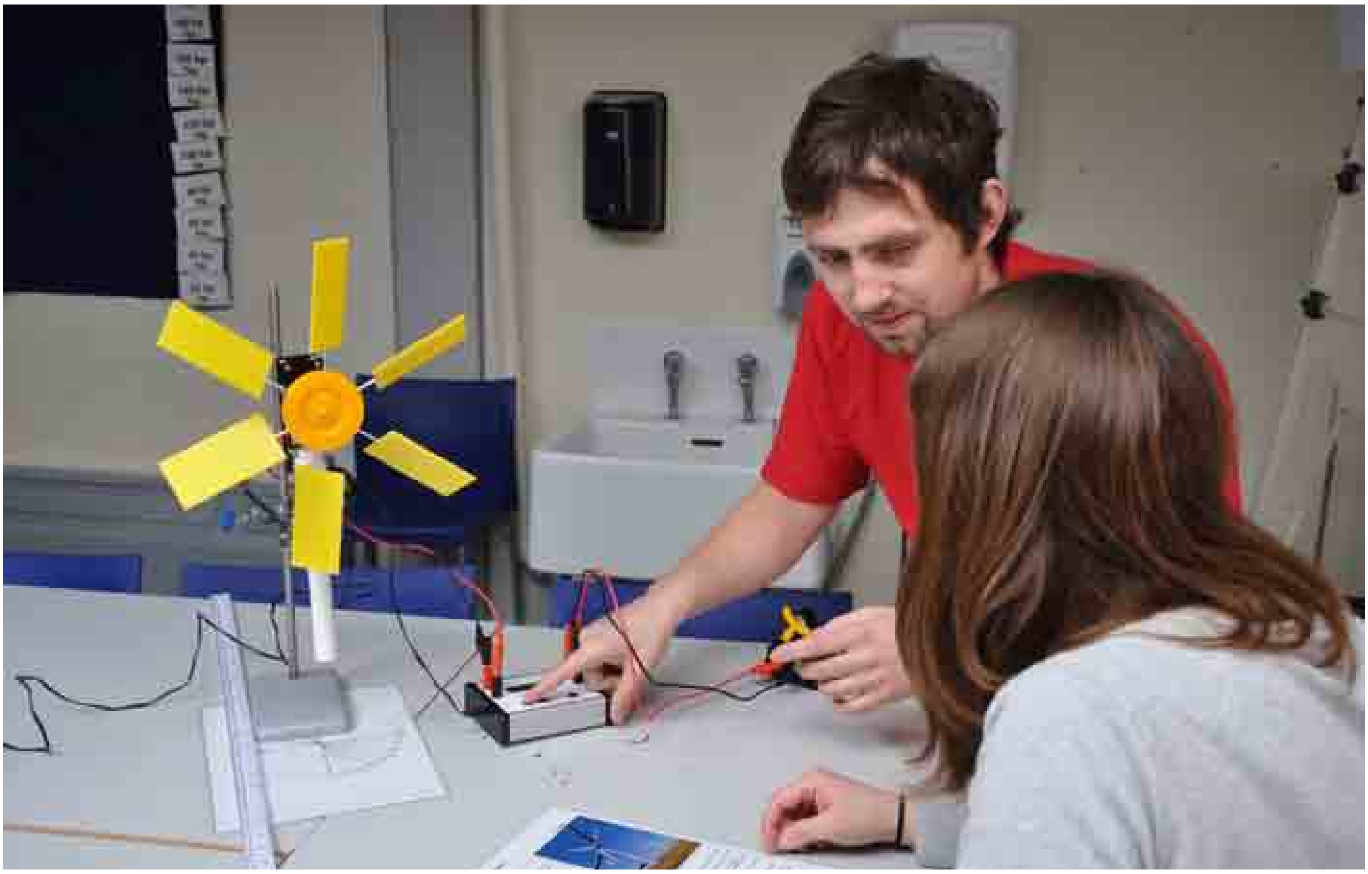
SUSTAINABILITY IN EDUCATION

Another area where our own sustainability journey has enabled us to expand and innovate is in our educational programmes. We have twelve years' experience in producing workshops and themed days for school groups to support and enrich areas of the national curriculum. In recent years, alongside our sustainability work, we have developed programmes in which we combine talking about sustainability issues, a growing priority on the curriculum, with using At-Bristol as a case study. We can engage and inspire students with the building they are visiting and perform activities using real data from our green technologies. With this development we now have sustainability programming covering all educational key stages.

One particular example is our workshop Sustainability at All Scales, funded by The Institution of Engineering and Technology, which puts into practice our philosophy of engaging people with our sustainability work and then expanding that to the global issues. In Sustainability at All Scales Key Stage 4 students begin in our planetarium looking at a picture of the Earth as a tiny blue dot as photographed by NASA's *Voyager 1* probe as it passed the rings of Saturn. From this inspirational starting point we talk about the Earth as a closed system and from there we talk about the issues of climate change, loss of habitat and energy demand, and then look at sustainable solutions. Next the students move to a laboratory where they debate energy on a national scale, looking at various options and experimenting by building functioning wind turbines. At that point we get them to think about energy consumption on an individual basis at home and at work, using At-Bristol's energy-reduction measures as a case study. Finally we give a tour around the building to look at our innovative technologies in use, with explanations of the underlying science.

Whilst Sustainability at All Scales is an on-going workshop for schools, we have also run similar theme days, such as The Co-operative-funded Green Schools Revolution LIVE for 500 pupils in a day. At-Bristol also provides continuous professional development for teachers through the Science Learning Centre South West where we again make use of our sustainability credentials, such as by holding events showcasing creative ways for teachers to include sustainability in their lessons.

The jewel in the crown of At-Bristol's sustainability engagement work is our new exhibition *Our World – no more waste*. Funded by the SITA Trust, the exhibition is underpinned by Earth system science and themed around the four main cycles of rock, water, air and life. The content investigates the mechanisms by which planet Earth recycles all of its materials indefinitely within a sealed and sustainable system to provoke thinking into how people use, recycle and dispose of materials. For *Our World – no more waste* At-Bristol's in-house exhibitions team used a range of novel and cutting-edge approaches in designing and constructing the exhibits: we used real data from the Met Office on a computer-generated globe showing weather patterns; there is a timeline with an interactive projection system where visitors can startle, carry or even recycle creatures from the last



▲ **Figure 1. A student learning about renewable energy by building a functioning wind turbine.**

▲ **Figure 2. The webcam that projected the installation of the solar panels gave viewers real-time information of how it was done.**

Figure 4. At-Bristol visitors can start to have an appreciation for Earth as a sealed system after looking into an ecosphere.

460 million years; we worked with a local university to extract a soil core and investigate its contents; there is an ecosphere (see **Figure 4**), a sealed ecosystem that presents a microcosm of our own planet, where visitors can watch the algae and shrimp that live inside and view the recycling of materials at the molecular scale by using a touch screen displaying a mixture of text, animations and pictures to start to appreciate the same processes happening across our planet.

In keeping with our sustainability mission the materials and processes used for constructing the exhibits were carefully considered as part of our *Cradle to Grave* exhibit workshop philosophy – we manage the lifecycle of exhibits from design and construction, to maintenance, reusing the materials to make new exhibits.

SUSTAINABILITY AT PUBLIC EVENTS

It is not just school children who have a chance to learn about sustainability through the lens of At-Bristol's sustainability drive, we also take our sustainability demonstrations out to public events like the Bristol Festival of Nature. We are always trying to find new ways of sharing our sustainability mission with a wider pubic. For example, when our photovoltaic array was being installed on the roof we set up a webcam so that people could watch it being built. At the same time we set up a Twitter feed, @BrianRoboFalcon[2], which reported on the construction of the array from the perspective of the robotic seagull deterrent (that looks like a peregrine falcon) used to protect it. Whilst giving updates on the progress of the array, @BrianRoboFalcon also explained the photoelectric effect, renewables and carbon dioxide emissions, and has remained as a popular and unique sustainability mascot for At-Bristol.

On a more serious note we used the installation of our photovoltaic array as an opportunity to hold a public debate for adults on renewables and the feed-in tariff. The debate was funded by Sciencewise-ERC, an organisation that "develops and commissions public dialogue activities in emerging areas of science and technology"[3] and the results were passed to the government to inform the policy-making process.

TEACHING BY EXAMPLE

We in At-Bristol have also found ourselves the subject of study in the area of sustainability, by hosting project placements for the students of neighbouring academic institutions. Environmental Engineering postgraduate students from the University of the West of England have used At-Bristol to conduct energy audits of our cutting-edge systems and as a teaching resource, whilst University of Bristol Atmospheric Chemistry postgraduates have studied the efficiency of our ventilation systems. As well as the sustainability of our building being studied, our sustainability engagement work itself is a topic for research with Masters students in Science Communication from the University of the West of England. One particular placement has looked at on-site sustainability interpretation, comparing At-Bristol with a range of other science centres to make recommendations on the best ways to engage the public with these complex, contentious and topical issues. Our work with academia brings the latest sustainability thinking into At-Bristol, using their contributions to further improve our own sustainability and share contemporary developments with the public.

An important element for us in becoming a hub of sustainability engagement in the industry has been in the promotion of our work. Our sustainability credentials now feature on our marketing materials and social media, we have received press and media coverage and appear as a case study on several websites. An outcome of this growing reputation is the relationships it has allowed us to build, especially in the Bristol area, and these relationships give us the opportunity to spread our sustainability engagement work further.

The city of Bristol has won awards for being the greenest city in the UK and was recently awarded second-greenest in Europe, second only to Copenhagen. This is complemented by being in a region with a growing green technology industry, which is occurring at a time when the need to engage, educate and inspire the public around sustainability issues is an emerging field, in which At-Bristol finds itself with an important role to play. We work closely with organisations like Bristol Green Capital, The Schumacher Institute and The Cabot Institute, helping them in the area of engagement, and therefore At-Bristol now regularly hosts the highest profile sustainability talks and debates in the region.

Bridging the gap between sustainability sciences and the public is an increasingly significant theme for At-Bristol and the scope for this work grows with the more relationships we build. But this is not just an issue limited to our region: there is an ever-more-important role for all science centres to work in sustainability engagement across the UK. Further afield there are related projects through Ecsite (the European Network of Science Centres and Museums), and the international Association for Science–Technology Centres, all recognising the importance of not only educating the public in sustainability issues but being a forum for debate and a source for inspiration as well. In all these projects it is important that the organisations themselves use the latest technologies and thinking to improve their environmental performance. Through this process they will truly be able to engage the public with sustainability, validated by the insights and expertise gained through their own journeys. ES

Chris Dunford is At-Bristol's Sustainability Officer. For the last two years he has worked to improve the organisation's environmental performance and build partnerships in the area. With an MSc in Science Communication and eleven years' experience in pubic engagement with science, Chris has worked to incorporate At-Bristol's sustainability drive into its vision "To make science accessible to all".

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Engaging policy-makers with environmental science

Clare Wilkinson and **Emma Weitkamp** give guidance on how best to communicate with policy-makers.

In recent years environmental scientists and researchers have been increasingly encouraged to communicate about their research to a variety of audiences, including policy-makers, pressure groups and more general audiences. In the UK, approaches such as the Research Council's Pathways to Impact incentivise researchers to consider plans for public engagement, as well as influences on policy and a range of other social and economic impacts. In addition, in 2014 the Research Excellence Framework will, for the first time, seek to consider how researchers have created impact from their past research.

At the same time, the concept of evidence-based policy has emerged, where scientific evidence is seen to play a key role the policy-making process. Drawing on the concept of evidence-based medicine, evidence-based policy-making is gaining ground amongst local, national and international policy-makers. With policy-makers increasingly open to incorporating scientific evidence at all stages of the policy cycle (see **Figure 1**), researchers now need to consider how best to reach this audience.

We know that a variety of factors, beyond these institutional agendas, encourage scientists and researchers to communicate about their work and participate in public engagement activities and many of these factors also apply to motivations and barriers to communicating with policy-makers. Individual motivations play a large role, such as researchers' attitudes to the role of public engagement with scientific issues and confidence in being able to engage via such settings[2]. From a professional perspective, scientists are often motivated to increase understanding and information around their fields of work, in particular in socially relevant areas[3]. However there can also be barriers, such as concerns about the time it takes and potential rewards[4]. Communicating beyond one's professional barriers can be a mystifying and daunting process, in particular when environmental issues, such as 'Climategate' reach the front pages[5]. However, communication, whether direct or via popular media, is perceived to play a crucial role in setting policy-makers' agendas.

For members of the scientific community building a professional reputation, publishing in high-profile journals or creating knowledge brokerage opportunities, have all been identified as ways via which policy-makers may be accessed[6]. However the communication trail is far from straightforward and the expectation of a linear or transmission model from scientist to policy-maker has long been rejected[7]. From the policy-makers' perspective the difficulty in finding and accessing the most relevant reports, the rare use of peer-reviewed journal articles, and the problem in identifying appropriate experts, in addition to the pressing time frame in which some of this information is often needed can create problems[8].

THE SEVEN KEY ISSUES

Through our work with policy-makers at national and European levels, we have developed seven key issues researchers need to consider when seeking to engage policy-makers with their research[9].

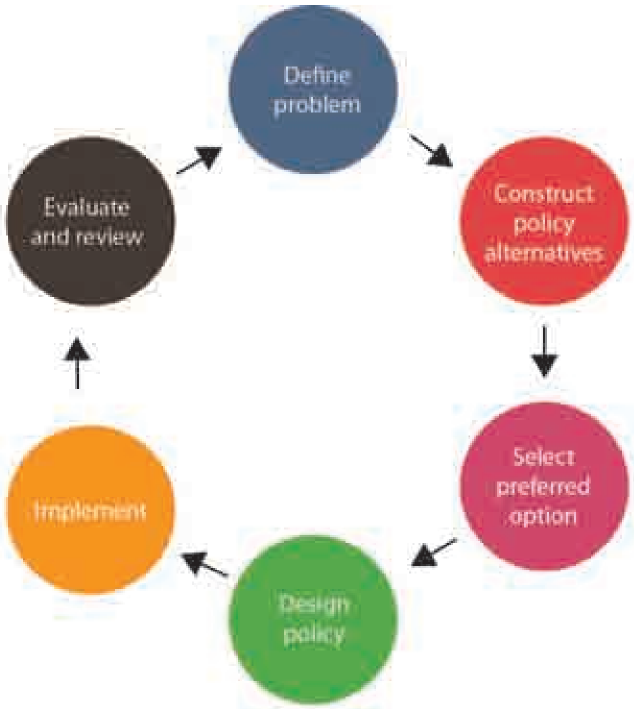

Figure 1. The Policy Cycle (adapted from Young & Quinn, 2002[1]).

- Know your policy-maker – knowing who to talk to, when to talk to them and what they would find useful for policy, can improve communication.

- Know the policy areas – different areas within environmental policy-making have different evidence needs (e.g. in terms of quantitative versus qualitative data), recentness, and scope (e.g. European, national or local scale)

- Consider policy stage – different kinds of evidence are needed at different stages of the policy cycle, for example a broad analysis of issues may be needed during policy formulation, while impact analysis may be more useful during the evaluation stages. Knowing what policies are upcoming or in progress can also help you tailor your communications.

- Understand the science–policy relationships – policy-makers may see science as primarily raising awareness of policy issues and impacts, or evaluating policy assumptions. Working with science, the role of policy is then to translate this into behavioural change and acceptance from the public.

- Assess the policy relevance of research – placing research evidence in a context that is clearly relevant to policy helps policy-makers to engage with findings. This can be by making clear links between drivers and impacts of policy and your research.

- Consider indirect routes – consultants are often used by policy-makers to gather evidence. Environmental scientists could capitalise on these links by choosing communication strategies that reach consultants as well as directly reaching out to the policy community. For example, researchers may choose to make links with environmental consultants providing services related to their field of expertise. Establishing such relationships can provide formal and informal opportunities to inform their working practices.; and

- Think about long-term implications – your research may not end up directly quoted in policy, but it may be the spark which spurs policy-makers to commission further research.

It is also worth noting that communication between the research and policy communities should not be seen as one way. Involvement with policy-makers can, and perhaps should, influence research itself. As such, opportunities for communicating and engaging with policy-makers should not be viewed as a top-down or one-way approach, but as an exchange of information, ideas and needs. Involving policy-makers at the early stages of research projects can help shape these to produce evidence that is more suited to policy-makers' needs. Such research has a greater chance of directly influencing policy.

Knowledge brokers can play a role in facilitating the transfer of evidence from the scientific to the policy community:

> *"The intent of knowledge brokering for developing environmental policy is to enable decision makers to acquire, value and consider expertise that they would not otherwise obtain or incorporate into their decision making."* (Michaels, 2009[10])

An example of such a knowledge-brokering service is the Science for Environment Policy News Alert service. Science for Environment Policy[11] is a free news and information service designed to help policy-makers keep up to date with the latest environmental research that supports the design, implementation and regulation of effective policies. It was first established in 2005, when it comprised an emailed bulletin (the News Alert) and an online archive for News Alert articles. Science for Environment Policy has since expanded to offer a range of outputs under a range of headings including Thematic Issues, an online database of policy-relevant studies (the Research Repository), briefing papers on emerging topics (Future Briefs) and In-depth Reports on key policy topics.

A recent evaluation of the service indicates that it is highly valued by both policy-makers and researchers as a mechanism that facilitates the transfer of research evidence into the policy community. Readers report that the service makes it easier to use science in policymaking and helps them to keep track of the latest scientific research that would be challenging to do individually. Researchers (24 per cent) report being contacted by policy-makers when their research has been reported in the service, suggesting that it is acting as a mediator between these communities. Specialist media, such as Science for Environment Policy, offer an opportunity for researchers to reach out to the policy community, providing a relatively simple way to begin the process of engaging policy-makers with research. This could be supplemented with more targeted strategies designed to gain the attention of specific policy-makers.

In summary, whilst communicating about research can have its challenges, all sorts of mediating groups and organisations are available to support researchers. This includes providing training (for example, the European Commission maintains a useful guide for science communication and journalism courses across Europe[12]), resources and support (from the UK-based National Coordinating Centre for Public Engagement, for example[13] or making the effort to communicate a specific piece of research directly to policy-makers. There is no reason why researchers and scientists cannot

▲ **Figure 2. Urban vegetation, highlighting the importance of urban trees.**

also play a role in engaging policy-makers, as well as broader audiences, with the impacts of their research. **ES**

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Dr Emma Weitkamp is a Senior Lecturer in Science Communication particularly interested in how context can be used to facilitate engagement with research and controversial issues. Current projects include the Science for Environment Policy and SCOOP projects, which seek to facilitate the transfer of research into the policy community, and creative projects that seek to engage young people with science using narrative and storytelling, particularly in online environments (e.g. ScienceComics and SpaceJunkies). Emma is also based at the Science Communication Unit, UWE, Emma.Weitkamp @uwe.ac.uk

▲ **Figure 3. Plastic waste, a visable example of an enivronmental problem.**

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