The Why and How of Science Communication

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Summary

This chapter explores the fundamental motivations behind science communication activities – why they are important, and how they are best achieved. The chapter begins with an examination of the societal factors which have led to an increased need for scientists to communicate, reviewing various cultural influences at an international level. Key motivations for science communication are explored at individual, institutional and wider strategic levels. An overview of 'types' of science communication then leads into an investigation of the wide variety of mechanisms available to successfully communicate science. Advantages and disadvantages of the three main media formats (traditional journalism; live or face-to-face events; and online interactions) are explored, and case study examples used to highlight recent international best practice. Finally, the author provides a series of 'top tips' for anyone planning to become involved in science communication.

Clarification of Terms

This work draws on previous research in areas relating to science communication and public engagement. It is worth clarifying these terms before proceeding further, since use of such terms varies, both in different parts of the world as well as between different institutions in the same country. As discussed later in this chapter, 'public engagement' with science recognises the *mutual learning* that occurs by both publics and scientists during their interactions. As outlined by McCallie et al. (2009: 12), Public Engagement with Science (PES) involves scientists and publics working together, and:

> allows people with varied backgrounds and scientific expertise to articulate and contribute their perspectives, ideas, knowledge, and values in response to scientific questions or science-related controversies. PES thus is framed as a multi-directional dialogue among people that allows all the participants to learn.

In contrast, 'science communication' is taken by some practitioners to reflect a slightly more historical term that is often assumed to mean a one-way communication of knowledge from scientific experts to public audiences (see for example Research Councils UK, n.d.). However, other authors delineate a much broader definition, encompassing many elements of two-way communication that others would describe as 'public engagement', such as "the use of appropriate skills, media, activities and dialogue" (Burns et al., 2003: 191). For the purposes of this chapter any mentions of 'science communication' are assumed to relate to the broader definition.

Cultural Factors

A recent major review within the UK identified four key cultural factors that have influenced the separation of science from society, resulting in an increased need for scientists to engage with public audiences (Science for All, 2010a; Benneworth, 2009):

- The loss of expertise and authority of scientists
- A change in the nature of knowledge production
- Improved communications and a proliferation of sources of information
- The democratic deficit

These factors are equally valid in other parts of the world, especially within more developed societies. In order to answer the question 'why communicate science?' it is therefore important to first explore these factors in further detail.

Reduced recognition of expertise and authority

As noted by Yearley (2005: 122) "Trust is central to the business of science", however in recent years there has been a significant shift in how members of the public trust and defer to expertise relating to scientific topics. A special Eurobarometer report on Science and Technology in 2010 noted that within Europe the majority of citizens feel that "scientists cannot be trusted to tell the truth about controversial scientific and technological issues" (European Commission, 2010: 19). The increasing reliance of scientists on funding from industrial and private sources was the main reason given within this report for this reduced level of trust, however other factors also come into play. High levels of press coverage for major controversial scientific topics such as climate change, nuclear power or genetically modified foods have led to a wide degree of polarisation and uncertainty in public opinion (Ipsos MORI, 2011), a situation that is exacerbated by high profile disagreements between 'respected' scientists on either side of the scientific argument. If the scientists can't agree on the 'right' conclusion, so the argument goes, then why should either side be recognised as being in a position of authority? As Kerr et al. (2007) argue, there is also an increasingly wide range of recognised additional 'experts' who are outside the scientific discipline in question. This is particularly true in the case of the medical professions, where "expert patients", "lay experts" or "experts of community" are common (Kerr et al., 2007: 387). Finally, specific examples of scientific fraud (suspected or proven) have been given high profile and wide ranging media coverage, again arguably causing a reduced acceptance of the 'authority' of people in such professions amongst public groups. For example, when in 2005 it emerged that Woo Suk Hwang had fabricated key findings relating to reported successes in cloning developments, there were immediate concerns that "the episode will damage not only public perceptions of stemcell research, but science's image as a whole" (Check and Cyranoski, 2005). More recently, the 'Climategate' scandal (involving leaked emails from researchers which included describing a 'trick' approach to 'hide the decline' in global temperatures) has led to a noticeable reduction in public belief in global warming in America (Leiserowitz et al., 2010).

Changes in knowledge production and interdisciplinarity

Within the scientific sphere, research developments are arguably frequently achieved in a more interactive and interdisciplinary manner than in the past, requiring multiple inputs from different areas of expertise (Benneworth, 2009). This is particularly true in the case of 'Big Science' projects such as the Large Hadron Collider or the Human Genome Project, which require concerted effort, resources and funding from international collaborations in order to achieve a major scientific endeavour. In times of economic hardship it can be difficult for some public groups to appreciate such research, especially to the extent of significant financial investment. There is also the issue that such approaches challenge the more traditional models of scientific practice, a change which both publics and scientists may find difficult to accept.

These changes both in how knowledge is produced, as well as what areas of expertise are required, mean that public groups may place a lower value on science (and scientists), thereby increasing the need for communication efforts to overcome this issue.

Proliferation of communication channels and sources of information

With the increased use of technology in almost every aspect of our lives, traditional channels of communication are now being challenged. For example, teaching styles remained relatively consistent for perhaps 150 years in most countries, with the teacher at the front of the room instructing students to learn key facts by rote – a 'chalk and talk' approach. Alongside broader pedagogical developments, advances in computing and connectivity have caused educational technology to develop rapidly. Every day, young people are now using tools that their teachers wouldn't have dreamt of when they were at school, for example virtual learning environments or electronic voting handsets. These changes are also coming into effect at an ever younger age. An influential independent review of the primary curriculum (ages 4-11) in the UK included as one of seven key recommendations the need to "strengthen the teaching and learning of information and communication technology (ICT) to enable children to be independent and confident users of technology by the end of primary education" (Rose, 2009: 12). Outside the school environment, use of technology also enhances the collaborative engagement opportunities that are available, leading to members of the public not only consuming knowledge about science, but contributing their own ideas and views e.g. via blogs, podcasts and social media (Leadbeater, 2008).

Democratic deficit

As outlined by Benneworth (2009), recent changes in the nature of decision-making processes have created a 'democratic deficit', whereby political-scientific decisions are increasingly made outside of the public arena. This is in part due to the increasing complexity of governance, and the ever growing numbers and varieties of stakeholders and lobby groups. The perceived deficit also relates to a wider public disconnection with democratic processes and voter apathy within many developed countries that is not specific to scientific topics. For example, many European countries face a particular challenge in engaging people within the member states in European issues, with an average voter turnout of 43% in the 2009 European parliamentary elections, in comparison with 66.6% average turnout in the most recent national elections (Eurostat, 2011). Arguably however, the European Commission is playing an ever greater role in determining the direction of scientific research, allocating a budget of nearly €7 billion for research and innovation in 2012 (Europa, 2011). If citizens are to be involved in decisions about the appropriate use of such funding, traditional voting approaches to democratic engagement will no longer suffice, and alternative approaches will need to be found.

Motivations for Science Communication

Institutional and Strategic Motivations

Bringing together the cultural factors noted above, a range of key motivations can be identified at institutional and national levels for encouraging science communication and/or science education. Osborne (2000: 226-230) provides an overview of the most common suggestions, identifying four key arguments:

- The *utilitarian* argument – The people involved will gain technical skills and knowledge that will be useful to them in their wider lives.
- The *economic* argument – Advanced societies require a technologically skilled workforce; science adds significantly to the overall output of a country (or region).
- The *cultural* argument – Science represents a 'shared heritage' and should be recognised as a wider part of our culture.
- The *democratic* argument – Science affects most major decisions in society, therefore it is important that publics are able to interpret basic scientific information.

As Osborne (2000) highlights, there are various strengths and weaknesses to each of the above arguments, however they do represent the major motivations highlighted by institutions and national bodies to justify their support for science communication. Additional suggestions include "To win support for science", "To make the world a better place" or "To be ethical, accountable and transparent" (Science for All, 2010: 7). Each institution (or country) will generally exhibit a combination of many of these arguments.

Individual Motivations

From the perspective of individual researchers, Research Councils UK has produced an excellent overview of the benefits to being involved in science communication activities, which include:

- Skills development
- Career enhancement
- Enhancing your research quality and its impact
- New research perspectives
- Higher personal and institutional profile
- Influence and networking opportunities

- Forming new collaborations and partnerships
- Enjoyment and personal reward
- Additional funding
- Increasing awareness of the value of research to society
- Increasing student recruitment
- Inspiring the next generation of researchers

(Research Councils UK, 2010: 30)

Few comparative international studies exist regarding scientists' motivations to become involved in science communication, however those that have been reported demonstrate some interesting trends. Within Argentina, Kreimer et al. (2011: 42) report that

> 'altruistic' motivations, such as a 'sense of duty', 'raising awareness of the discipline' and even 'transmitting the importance of science', predominate over motivations that are 'strategic' or 'political' (in a broad sense), such as 'fighting the irrationality of the public', 'justifying the use of public funding', 'attracting students to my discipline' or 'generating additional funds'.

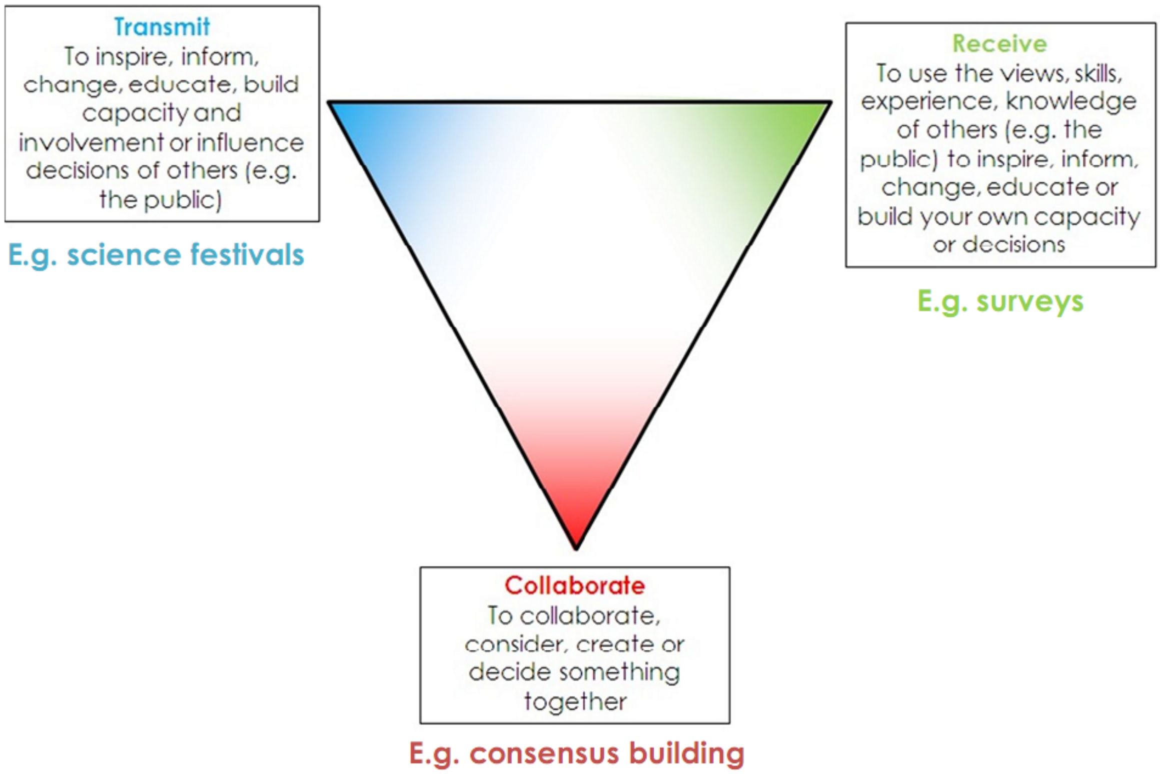
These scientists are clearly encouraged to participate in science communication activities by societal, not institutional reasons. An extensive survey involving 1485 research scientists in the UK in 2006 demonstrated that the main reasons related primarily to perceived external needs, with the most popular motivation (35%) given as "To ensure the public is better informed about science and technology" (People Science Policy, 2006: 28). More recent work in the UK has also supported widespread anecdotal claims relating to the importance of "informal and 'fun' elements" enhancing the enjoyment of the scientists involved, whilst other researchers are motivated to "provide something beneficial to the audience" (Wilkinson et al., in press: 11).

Types of science communication

Various categorisations have been developed to distinguish between different types of public engagement which can usefully be applied to science communication (see for example Rowe and Frewer, 2005; Bucchi, 2008; McCallie et al., 2009). The fundamental concept shared by all the models is the distinction between 'deficit' and 'dialogue' approaches. In the former, the assumption can be that the audience members lack necessary knowledge about scientific concepts, and therefore communication *from* scientists *to* a public audience is required (Gross, 1994). Conversely, a 'dialogue' approach (occasionally known as a 'contextual model') involves a two-way exchange of information between scientists and publics. As described by Miller (2001: 117):

> This approach sees the generation of new public knowledge about science much more as a dialogue in which, while scientists may have scientific facts at their disposal, the members of the public concerned have local knowledge and an understanding of, and personal interest in, the problems to be solved.

Some authors have extended this further, for example Rowe and Frewer (2005:255) describe a three-pronged approach consisting of *Communication* (information flowing from the 'sponsor' – scientific organisation – to public representatives), *Consultation* (direction of travel of information from public representatives to the sponsor), and *Participation* (two-way communication between sponsor and public representatives). Bucchi (2008:69) outlines a similar multi-model framework involving *Transfer*, *Consultation* and *Knowledge Co-Production*. Whilst these approaches capture the main types of communication methods, they can encourage a tendency to place all activities within one or more 'silos' which are considered completely separately from each other. A more nuanced approach has recently been developed by the Science for All Expert Group in the UK, consisting of the 'Public Engagement Triangle' as shown overleaf (Science for All, 2010b). This 'triangle tool' identifies three key communication approaches: *Transmit*, *Receive* and *Collaborate*, which are broadly in line with the categories previously identified by Rowe and Frewer (2005) or Bucchi (2008). However the strength in the triangle approach is that it recognises that these approaches do not work in isolation, but instead as the apexes of various spectra. Any one science communication activity is likely to involve a blend of these three approaches according to the needs of the audience(s) and the scientists involved.



(Science for All, 2010b)

A similar 'spectrums' approach has been suggested by other authors, most notably McCallie et al. (2009:43-46), who produced a three dimension model with axes relating to "role of the public, role of STEM [Science, Technology, Engineering and Mathematics]-related experts, and the content focus of the discussion". The main advantages of such 'spectrum' approaches are their simplicity, as well as their ability to prompt conversations and reflection between the people involved in planning such activities.

How to communicate science

There are a vast range of approaches to engaging public audiences with scientific concepts; Mesure (2007) identified over 1500 active initiatives within the UK alone. It is therefore understandably impossible to cover every approach within this chapter. Instead, a series of contrasting case studies are presented in order to provide a flavour of the variation and creativity involved in different successful approaches. The reader is encouraged to consider where each of the examples outlined below might be placed on the public engagement triangle – and how that placement might shift depending on specific circumstances. Broadly speaking, there are three main forms of media used in science communication: traditional journalism; live or face-to-face events, and online interactions. Each approach has its associated pros and cons, as outlined in the table overleaf. *Note that these issues have been identified in the general case, although obviously specific situations may differ.* There is a wide range of excellent existing work relating to becoming involved in science journalism via traditional media. For example Weitkamp (2010) provides a practical overview of science writing, including news writing and news structures, as well as key tips regarding writing for different media. Murcott (2010) explores the history of science broadcast journalism, outlining different types of broadcasters and programme genres, and includes recommendations on how to get a story to air. Other key texts in this area focus on science journalism (Dunwoody, 2008) and radio and other audio (Redfern, 2009), whilst Holliman et al. (2009) explore aspects relating to public engagement via popular media. Furthermore, public participation activities operating on a face-to-face basis have also been covered extensively in previous literature. Rowe and Frewer (2005) noted at least 100 different types of 'participation' mechanisms, separate to other 'communication' and 'consultation' approaches, whilst People and Participation.net[1] provides details on examples of 60 different methods.

In order to avoid repeating existing high quality content this chapter will therefore focus on case studies of live (or face-to-face) science communication activities, as well as some indicative online interactions that are outside the mainstream tradition of science journalism. Four separate case studies will be presented, drawing on a wide range of international best practice in the field. Note that these case studies are not designed to be representative, and as noted above, there are plenty of other modes of public engagement to choose from. However they do provide an indication of the breadth of possibilities that exist. For other complementary case studies see for example McCallie et al. (2009: 34-46) or NCCPE (n.d.).

[1] http://www.peopleandparticipation.net

Medium	Advantages	Disadvantages
Traditional journalism (both print and broadcast) e.g.: • Newspapers • Magazines • TV • Radio	Large potential audiences (potentially millions of people) High quality due to being overseen by professionals (e.g. journalists) Traditionally recognised as agenda setting Audience selection is possible through appropriate choice of publication/programme	Scientists lack control of how the media covers their work Tends towards one-way communication Frequently provides a limited or superficial focus
Live or face-to-face events e.g.: • Public lectures • Science Centres and Museums • Debates & dialogue • Science busking • Sci-art • Science cafes • Science Festivals	More personal – involves a direct interaction between scientists and publics Scientists are able to better control the content Engenders two-way communication Can involve partnering with other external organisations with complementary expertise	Limited audience reach (tens to thousands of people) Resource intensive, leading to low sustainability of activities Can be criticised for only attracting audiences with a pre-existing interest
Online interactions e.g.: • Internet sites incl. online journalism • Blogs, wikis and podcasting • Facebook, twitter and other social media • Citizen Science	Large potential audiences (potentially millions of people) Can allow direct interaction between scientists and publics Initial content can be controlled by the scientists… Caters for both one-way and two-way communication, depending on audience's preference Always accessible; suits the audience's time preferences	Can encourage superficial or 'jokey' interactions …but it is very difficult to control how the content is picked up by others Requires regular attention to maintain profile Requires key communication skills that may not be immediately apparent

Adapted from Bultitude (2010)

Public Talks

One of the most familiar forms of science communication is the public lecture. The traditional format is very similar to a normal taught class or lecture, with a single speaker presenting on a specific topic, and the audience listening. Use of question and answer sessions at the end of the presentation can allow for some interaction between the speaker and the participants, however generally public lectures are considered a 'transmission' form of communication. The Christmas Lectures hosted by the Royal Institution of Great Britain (the RI) are perhaps one of the best known and longest established examples, which (apart from a short break for the second world war) have been running continuously since 1824 (James, 2007). In addition to the live audience, since 1966 the Christmas Lectures have been televised annually, reaching international audiences of more than one million people. In the early days Humphry Davy and Michael Faraday (and others internationally such as Hans Christian Ørsted in Denmark) introduced innovations to the public lecture format to greater improve their popularity, which included targeting 'juveniles' (people aged 15-20) and incorporating demonstrations and practical experiments that wowed the audience members (James, 2007; Pearce Williams, 2008). This popularity was widely perceived; in a public profile of Faraday, the Illustrated London News (1861, cited by James, 2007) wrote:

> For the last eight seasons Professor Faraday has undertaken this task with a modesty and power which it is impossible to praise too much. There can be no greater treat to any one fond of scientific pursuits than to attend a course of these lectures.

James (2007) also notes that the popularity of the afternoon lectures at the RI was so high in Davy's time that it led to the creation of the first one-way street in London, clearly emphasising the value and esteem accorded to the events by the wider population.

Public lectures have continued in much the same vein since the days of Davy, Faraday and Ørsted, with the ability to present a lecture being a standard requirement of most scientific roles (for tips on presentation skills for public science communication lectures see Bultitude, 2010). However, in part due to the cultural factors raised above, increasing importance is being placed on the inclusion of 'interactive' elements within public lectures, in order to ensure greater involvement of the audience. A more recent innovation along these lines used electronic voting handsets to allow the audience to 'choose their own lecture' – i.e. select from a range of options offered by the presenters, in order to allow the audience to take more control over the direction of the lecture (Bultitude and Grant, 2006). The international Café Scientifique network has taken the level of interactivity even further, instituting informal events involving a speaker and an audience that occur in public locations such as cafés and bars (Grand, 2009: 210):

> Cafés Scientifiques classically start with a short introductory talk by an 'expert'. On average, this introduction lasts for no more than 25 minutes, and in some cases as few as 10. Most cafés eschew technology – so no slides, microphones or dimmed lights to emphasize a hierarchical divide between speaker and audience… After the break comes an hour or so of discussion, questions, comments, thoughts and opinions between the speaker and the audience, the audience and the speaker and the audience and the audience.

Unlike traditional public lectures, the emphasis within Cafés Scientifique is very much on a symmetrical relationship between the speaker and the audience. As discussed previously, this does not necessarily mean that *all* events must involve high degrees of interactivity, but that it is important to consider whether greater audience involvement may result in higher levels of engagement and learning – both for them and for the presenter.

Science Comedy for Adult Audiences

The combination of science with humour has previously been shown to be beneficial, for example enhancing learning as well as connection between participants (Armstrong, 2002). Use of humour has also been found to be beneficial in adult-child relationships, especially in pre-teen adolescents (Lovorn, 2008). More recently, innovative initiatives have been developed which are specifically aiming to engage adult audiences through the combination of science with humour. *Bright Club*[2] describes itself as "the thinking person's variety night, blending comedy, music, art, new writing, science, performance, and anything else that can happen on a stage" (UCL PEU, n.d.). It is delivered collaboratively by a university and a comedy promotions company, and involves university staff and students performing short comedy routines, compered by a professional comedian. One of the most significant achievements of the *Bright Club* format is its success in accessing young adult audiences outside of formal education (in this case aged between 20-40), who are often considered to be hard-to-reach through traditional means. Audience members generally already participate in wider cultural activities (such as variety nights or standup comedy); the combination with scientific topics provides a unique opportunity to engage such audiences with science. There is no overt expectation that audiences will 'learn' anything from the event, although audience members reported being pleasantly surprised that learning does occur (Moore, 2010: 4):

> Well, you come to a comedy night and you expect to be entertained and amused, but you don't expect to learn anything! I really liked the mix of science and comedy ... It is a fantastic concept. – *Audience member*

The combination of science and comedy is novel to most audience members and, as noted by the above comment, is very welcome to them. Other audience members also emphasised that the learning was not only content-focused:

> This learning was not just about a subject, but about the people behind the subject and the practice of research. Thus, it is not just about making a subject funny, but bringing to life the processes and people behind the research. – *Audience member*

A key factor in the success of *Bright Club* events is their use of a broad common theme to draw together the contributions from different speakers. Themes to date have included Lust, Crime, Food and Power, all of which provide opportunities for interdisciplinary contributions. A further strength of this format is its attractiveness to university staff and students who are approached as possible speakers. Although they described their potential involvement as very 'scary', it has been shown to be "an effective tool for generating interest in public engagement from staff and students. Bright Club is an imaginative

[2] http://www.brightclub.org/

technique which has harnessed previously untapped interest in public engagement" (Moore, 2011: 12).

The Science Museum in London has similarly developed specific events and activities aiming to reach adult audiences. Known as the *Lates*[3], the events involve specific adult-oriented talks and activities held one evening a month, as well as an opportunity for adult visitors to explore the museum without children being present. Again, the events are very successful at reaching young adults (particularly females), and audience evaluation of the *Punk Science* comedy shows performed at the *Lates* events indicate that there is a correlation between the comedic references in the shows and science content recalled by public participants (Grosvenor, 2010).

I'm a Scientist – Get me out of Here!

Within most countries, some of the most popular recent television programmes involve 'reality style' approaches that incorporate audience voting to retain/remove contestants. These range from participants completing set tasks in *Big Brother* and *I'm a Celebrity – Get Me Out of Here!* to music-related competitions such as *X-Factor* and *Pop Idol*. Within science communication these concepts have been creatively adapted to produce *I'm a Scientist – Get me out of Here!* (IAS)[4], which is now running in both Australia and the UK. IAS involves online interactions between school pupils and scientists, where the researchers are challenged to answer questions posed by the students within a limited time period. The students then vote on the scientists in phases, resulting in an overall student-selected 'winning' scientist by the end of the competition. The programme is supported by various teacher resources to extend the discussions further within the classroom, and operates through a closed forum to ensure pupil safety. The evaluation results are very positive; one participating student described IAS as follows (Pontin, 2010: 4):

> I'm a scientist is a website aimed at all teenagers – interested in science or not (but believe me, by the time you finish the project, science will have taken over your brain and made you love it for the rest of your life). – *Pupil Participant*

Whilst students were frequently nervous or a little reticent in their interactions at the start, they soon relaxed into the process of communicating with the scientists, and by the end most scientists report that they struggled to deal with the high number of questions being posed to them (Pontin, 2010). Furthermore, a key advantage identified within the IAS programme is its ability to present scientists as 'real people' (Collins, 2009: 2):

> Students wanted to know about the scientist's feelings about science and their jobs, what their jobs were like, day to day, how they got into science and what the scientists were like as people (interests, favourite foods, most embarrassing moments).

The IAS approach therefore develops participants' appreciation of science as *process* rather than merely facts and figures, and achieved a greater connection between scientists and pupil participants. Another key advantage was giving the pupils the 'power' to vote for their

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[3] http://www.sciencemuseum.org.uk/visitmuseum/events/events_for_adults/Lates.aspx

[4] http://imascientist.org.uk/ and http://imascientist.org.au/

favourite scientist; this not only provided an incentive for the scientists to answer as many questions as possibly clearly and succinctly, but also enhanced the pupils' engagement with the process.

Citizen Science

As mentioned above, in addition to the traditional news media channels (print and broadcast), there are increasing online and mobile options, such as wikis, blogs, podcasting, Twitter, and other social networks. The wide variety of channels subsequently creates difficulties in attracting an audience's attention, requiring increasingly sophisticated approaches to ensure that your message reaches the intended audience in an appropriate manner. Audiences must also be increasingly discerning about how they consume such media, requiring skills in both sourcing appropriate information but also in critically analysing its content, since there are fewer external 'checks' (such as editors or peer review in more traditional media).

Whilst this situation does create specific challenges, it also produces key opportunities for encouraging the engagement of different public audiences through novel means. One such opportunity relates to the 'Citizen Science' movement; the idea of involving members of the public directly in the process of research, usually via online mechanisms. A citizen scientist is "a volunteer who collects and/or processes data as part of a scientific enquiry" (Silvertown, 2009: 467). Much like the 'co-production' model described by Bucchi (2008), the intention is that the audience members are directly involved in the scientific process as it develops, and are additionally able to interact with scientists in the process (Brossard et al., 2005).

Various Citizen Science projects have developed in recent years, covering fields as diverse as ecology and environmental sciences, ornithology, astronomy and astrophysics, and climate modelling (Silvertown, 2009; Brossard et al., 2005; Citizen Science Alliance, n.d.). They roughly divide into two main groups: data-gathering exercises and data-analysis procedures. In the first case, participants contribute local observational evidence to assist in building a better understanding of a specific concept. For example, in the case of the Cornell Lab of Ornithology, "bird watchers report tens of thousands of bird observations" every day, which feed into a large information pool that is then analyzed by scientists (CLO, n.d.). The alternative model runs mainly through online environments, where members of the public participate in analysing large datasets via the Internet. This can be done passively on the part of the members of the public, for example both SETI@home[5] and climateprediction.net[6] are examples of distributed computing projects which run as background processes when a computer is idling, sending any interesting information back to the main server via the Internet. There are also more active forms of online analysis examples of Citizen Science projects, with Galaxy Zoo being the archetypal model in this category. In this case, participants classified images of galaxies taken from the Sloan Digital Sky Survey (Raddick et al., 2010).

[5] http://setiathome.berkeley.edu/
[6] http://climateprediction.net/

In each of the above Citizen Science scenarios, there are clear benefits to both sets of participants: the scientists and the members of the public. The scientists are able to achieve a far greater degree of robust analysis and scientific output than if they had been operating alone; the forms of analysis that are particularly suited to Citizen Science projects are often those that involve pattern recognition, where human judgement remains more effective than automatic computer processes (Zooniverse, n.d.). There is also evidence that the participants gain aspects such as greater knowledge, increased scientific thinking, a sense of community, and the opportunity to contribute to original scientific research, as well as more aesthetic elements such as 'beauty' and 'fun' (Trumball et al., 2000; Brossard et al., 2005; Raddick et al., 2010). More Citizen Science projects are frequently coming online; at time of writing there were ten contrasting projects in the 'Zooniverse'[7], covering topics ranging from galaxy identification and planet spotting to transcribing ancient Egyptian papyri or tracing past weather patterns from Royal Navy ship logs.

Top Tips

This chapter has drawn together existing literature and case studies to provide an overview of the 'how' and 'why' of science communication. However, such an overview would not be complete without some practical advice for people who are interested in becoming directly involved in science communication themselves. This section highlights the author's 'top tips' for science communication – if you follow this advice you should be well on your way to successfully interacting with public audiences about scientific concepts.

Tip #1: Know your audience

One crucial factor when working with public groups is that they are not an homogeneous group of clones: there is no such thing as 'the general public'. Each person in your audience will have their own interests, prejudices and concerns, and it is important to take these into account when planning your activity. In particular, in advance of your activity try to get a feeling for who your audience is likely to be, as well as what they will have in common. You can do this by consulting with the event organisers, or reflecting yourself on who is likely to attend and what their backgrounds are likely to be. By segmenting your audience into recognisable demographics (for example age, educational background, socio-economic group and/or existing levels of interest in science) you can then draw on the factors that your target audience will have in common. By appealing to their interests you are much more likely to properly engage them with scientific concepts. For example, within the UK six key 'audience clusters' have been identified according to their general attitudes towards science: the 'concerned', 'indifferent', 'late adopters', 'confident engagers', 'distrustful engagers' and 'disengaged sceptics' (Ipsos MORI, 2011: 71). Members of these groups share common factors, which means that it is possible to identify specific mechanisms and/or content that is most like to appeal to members of that group.

[7] One of the most prolific Citizen Science collaborations, http://www.zooniverse.org/

Tip #2: Think creatively

It is important not only to challenge your audience, but also challenge yourself when developing new science communication activities. Of course if you are new to science communication then start off with one of the tried and tested models (for example one of the formats identified above). However when you are a little more comfortable with delivering science communication activities then think about what you can do differently to engage your audience more deeply. This could include appropriate use of 'emotional hooks' that are likely to be of interest to your audience, for example 'novelty, incongruity, curiosity, humour, imagination, choice, control, empowerment, involvement, challenge, complexity, comprehension, social interaction and relevance' (McCrory, 2010: 97). It is important to reach your audience affectively as well as cognitively if you truly want to engage them; likewise, you will get more out of the activity if you feel an emotional attachment to being involved. These emotional hooks could be delivered through a slightly unusual format, a new demonstration or discussion topic, or involvement of other external people (for example patient group representatives) – in any case, if you bring your own creativity to the situation then the possibilities are endless.

Tip #3: Learn from others' experience

Whilst it is important to 'take ownership' of any science communication activity that you deliver, be aware that other practitioners may have been involved in delivering similar events for many years. Just as you wouldn't publish a scientific paper without first seeing what had been published previously, it is worth exploring what learning has already been achieved in the area of science communication that you are interested in. You can access such information through online repositories in various parts of the world, for example:

- *Informalscience.org* describes itself as 'A resource and online community for informal learning projects, research and evaluation'. Although it is mainly US-based there are plenty of submissions and forum posts from other parts of the world, including a searchable index of projects, research and evaluation resources.
- *Collective Memory*[8] – This UK-based resource is a database of evaluations from a diverse range of science communication initiatives. It has been deliberately designed to encourage sharing of good practice amongst practitioners from across the science communication community.
- *Research2practice.info* provides brief summaries of recent peer-reviewed educational research, thereby saving readers the hassle of separately trawling through the literature for elements that may be relevant.
- *The Exhibit Files*[9] is 'an online community of people who make exhibits – a place to connect with colleagues, find out about exhibits, and share your own experiences'. It contains both case study examples as well as external reviews conducted by other members of the community.

[8] http://collectivememory.britishscienceassociation.org/
[9] http://www.exhibitfiles.org/

Tip #4: Evaluate your own activities

In line with learning from others' experiences, it is crucial to reflect on and evaluate your own activities throughout the process of delivering them. This should include both monitoring (measuring how many people attended, plus basic quantifiable aspects of your event) as well as impacts (what did the participants – public groups, scientists and event organisers – get out of it). There are a wide range of evaluation guides available publicly; some of the best are:

- *Evaluation: Practical Guidelines* (Research Councils UK, 2011) – This guide has been specifically designed for researchers who are seeking to engage public audiences. It provides a very practical perspective, and does not assume any prior experience in either public engagement or evaluation. This guide includes extensive example questions as well as a wide ranging 'further reading' section which outlines an excellent variety of further resources relating to evaluation.
- *Ingenious Evaluation toolkit* (RAEng, n.d.) – Although this toolkit was originally developed for a specific funding scheme (the Royal Academy of Engineering's *Ingenious* awards), it provides excellent practical advice relating to evaluating science communication projects, including a series of 'FAQs' and a 'bookshelf' of other external resources which is regularly updated.
- *The User Friendly Guide* (Frechtling Westat, 2010) – An extensive but (as the name suggests) easy to use handbook for project evaluation. This guide provides an overview of all the key processes in evaluation, ranging from justifying its purpose, to developing an evaluation design (including choice of appropriate methods), reporting, and ensuring appropriate rigour in more complex multi-site situations.

Tip #5: Enjoy yourself!

Enthusiasm is infectious; your audience will be more likely to become interested in a topic if they see that you are passionate about it. Choose topics that you are fundamentally interested in, and remember that science communication is a two-way process – so you should be learning and engaging as much as members of your audience.

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