5.2 Objectives, audiences, and formats

Science communication is not a new phenomenon. In the UK, the concept of scientists communicating their research findings to non-scientists dates back at least as far as the early 19th century, when scientists such as Michael Faraday and Humphry Davy spent a considerable amount of time and money trying to popularise science. However, as an academic discipline, science communication is a relatively new field, which in the UK has undergone three main stages [1, 2]: scientific literacy, Public Understanding of Science (PUS) and Public Engagement with Science and Technology (PEST). In moving through these three stages, the ideology of the communication of science has developed from a primarily deficit model (in which scientists try to 'fill' gaps in the knowledge of the public) into one which encourages two-way dialogue between scientists and non-scientists.

Science communication as an academic discipline covers a broad range of topics [3, 4]. However, as the majority of research into the relationships between scientific knowledge, technological systems, and society tends to be done by STS (Science and Technology Studies) scholars, perhaps too little of the current recommendations and accepted best practices are communicated to scientists who are actively engaging with (or planning to engage with) non-scientists [5, 6]. Furthermore, the field of science communication tends to defy any singular definition [7], with any such attempt needing to reflect: the variety of formats in which such initiatives can be implemented [8], the wide spectrum of target audiences [9], and the range of objectives [10]. This multi-faceted nature is also illustrated by the many terms that are used when discussing outward-facing science communication, such as: widening participation, knowledge exchange, public engagement, and outreach [11]. As well as institutional and national biases towards the 'correct use' of these terminologies

there often exist personal nuances in terms of their interpretation, depending on how individuals perceive science communication to fit into their individual research practices, and beyond.

Based on the current science communication literature, and our own experiences, the following broad definitions are offered:

Outreach: a one-way discourse, in which scientists communicate their research to non-scientists.

Public Engagement: a two-way dialogue, in which scientists converse with non-scientists in a mutually beneficial manner.

Widening Participation: any initiative that engages with social groups under-represented in higher education, in order to encourage them to attend university.

Knowledge Exchange: any initiative that involves engagement with businesses, public organisations, and third sector organisations (e.g. charities).

We acknowledge that there is still some overlap between these definitions. For example, a science talk at a local school given by a UK-based university researcher might be classed as being outreach, widening participation, and knowledge exchange. In this example, the researcher might classify the initiative as outreach, the university's widening participation team may catalogue it as widening participation, and the university's knowledge exchange offices could acknowledge it in their records for UK Research and Innovation.

Widening participation and knowledge exchange as defined above are beyond the scope of this chapter, which will instead focus on outreach and public engagement, these being the most likely to be encountered by the majority of scientists. For brevity, we will use the term 'science communication initiatives' to refer to both outreach and public engagement initiatives unless otherwise stated.

Exercise: planning your initiative

When you are developing any science communication initiative you should begin by asking yourself these three questions:

What is your objective? For example, do you want to raise awareness of the importance of diversity in scientific research? Are you interested in finding out the opinions of a local community group to inform your work on flood risk mitigation strategies?

Who is your audience? How does this help you to achieve your objective, and how will you reach them? For example, if your objective is to raise awareness of air pollution amongst pensioners then how will you engage with this community?

What format will you use? This needs to enable you to both achieve your objective and be appropriate for your target audience. For example, if you want to engage with local farmers in order to better understand the soil quality of arable farmland in the region, then a series of workshops might be more conducive than a one-off science talk.

Your objective is what will drive your science communication initiative, and as such it needs to be clear and achievable. You might also have a particularly aspirational long-term objective that can then be broken down into several short-term objectives. For example, your long-term objective might be for the health effects of air pollution to be more fully incorporated into your country's school curriculum. However, in order to achieve this, your short-term objectives might be to develop a game that is used in 30 local schools to raise awareness of the subject, and the organisation of five panel debates with educationalists and policymakers to discuss the potential for re-designing the curriculum. These objectives will depend entirely on what you want to achieve, and so the remainder of this chapter will instead focus on providing support for the other two questions, i.e. how do you engage with suitable audiences, and what are the practicalities of the different formats that can be adopted.

5.3 Different publics

When thinking about which audience you want to engage with, the term 'general public' or 'lay audience' is somewhat misleading, as in reality there are many publics [9]. Simply targeting an audience that are not scientists is ineffectual, as 'not being a scientist' is not generally an identity, behaviour, or characteristic that people tend to identify and group themselves according to [12]. In developing your science communication initiative, it is essential that you consider which publics you intend to target, and why. In some instances, you might not have a choice, as your audience may be pre-determined by a larger initiative of which yours is only a part. In which case, have you considered if this larger initiative is a suitable platform for achieving your objectives? For example, if your objective is to raise awareness of climate change amongst local business leaders, then organising a panel debate at a local primary school (during the working week) might not represent the most effectual targeting of a suitable audience.

When determining which audience to engage with, try to think beyond previously-engaged audiences. The reasons for this are twofold: firstly, working with familiar audiences risks trapping you inside an echo chamber, and secondly there are many audiences that are underserved and under-represented by both science and science communication initiatives, and as ethical scientists (see chapter 9) we have a responsibility to engage these audiences.

An echo chamber is an environment in which a person encounters only beliefs or opinions that resonate with their own, so that existing views are reinforced and alternative ideas are not considered. As scientists we should be breaking out of these echo chambers, moving away from the same, traditionally engaged audiences. Instead, we should be enabling more effective communication with publics that have a diverse range of demographic, socio-structural, and value-based characteristics [13]. Working with these underserved and under-heard communities presents barriers and challenges, but it also creates many opportunities for both advancing scientific research and re-considering what is meant by meaningful impact [14].

But how do you engage with these audiences? Begin by developing a relationship with a member of the community that you want to work with, ideally someone who is in a position of responsibility; for example, if you are interested in working with a local youth group then you might first make contact with one of the adult leaders. Developing this relationship may involve emails, phone calls, and meetings over a relatively long period of time before you are able to deliver any initiative, as it will be necessary to build trust, especially if the community that you intend to work with includes people who might be considered to be vulnerable. When developing your initiative, involve your contact in the community, as they will have a better understanding of how you can tailor your plans to the relative needs and experiences of the target audience. Also, think carefully about where the initiative will take place; while research institutes are often convenient, 'safe ground' for the scientists involved, for many publics they are inaccessible locations that present several physical and psychological barriers. Finally, in thinking about which communities to develop your science communication initiative for, have you considered the communities to which you already belong. For example, do you volunteer at a local charity? Are you a member of a sports club? Do you host a weekly games evening? These are all communities which you might consider developing an initiative for, helping to refine your objectives in the process. The benefit of engaging with such communities is that you already have a relationship with existing members, and will be naturally sensitive to their needs and experiences.

In developing any science communication initiative that involves scientists and non-scientists, you need to give thought to how you can level any so-called 'hierarchies of intellect'. These arise when there is a perception that one of the parties is an expert and the other is not [15], and can hinder meaningful discussions. Scientists might be experts in a particular topic, but non-scientists are experts in their own personal and professional capacities, and this expertise should be encouraged and highlighted in order to facilitate a more conducive environment. For example, if you want to develop a science communication initiative to find out what a rural community think about genetically modified foods, then create a platform in which non-scientists are asked to share their own expertise and knowledge, and where they are treated in a similar manner to the scientific 'experts' who are asked to do the same.

Once you have determined your audience and how you will reach them, you need to think about how you will frame your initiative. Framing was introduced in chapter 4 when discussing the importance of understanding your audience for science presentations. The advice that was provided there still holds, i.e. that understanding the needs and experiences of your audience is key to effectively framing any science communication initiative. Furthermore, in framing the way in which to discuss certain scientific topics, we also need to ensure that we avoid promoting false expectations [16], and to behave as ethical scientists throughout the process.

5.4 Working with children

The advice that has been given so far in this chapter has been of a purposefully general nature, as it is not possible to provide specific advice for all of the various publics that you may encounter. However, given that for many scientists one of the first outward-facing publics that they will work with may be children, we thought it beneficial to provide more detailed advice for developing and delivering science communication initiatives for this particular audience. In most instances, these initiatives will take the form of outreach (i.e. one-way discourses, in which scientists communicate their research to non-scientists), although this need not always be the case.

Working with children can be an extremely rewarding and enjoyable experience. However, it can also be demanding, difficult, and at times disheartening. It is arrogant to assume that you will simply be able to walk into a classroom, or a more informal setting, and instantly command the room because you are *a scientist*. Before developing and delivering an initiative aimed at children it is advisable to first get some relevant training and experience.

The STEM (Science, Technology, Engineering, and Maths) Ambassadors [17] are a national collective of volunteers who are dedicated to providing science communication opportunities in STEM subjects across the UK. In addition to providing training and advice, they also have a list of ready-made initiatives that are being run by schools or other organisations, which you can participate in to receive science communication experience.

If you are working with children in the UK then you need to have a Disclosure and Barring Service (DBS) check, to make sure that you are fit to work with children. Other countries have similar requirements, and there is normally a small fee attached to having one of these checks performed, but your research institute will usually pay this for you if you are delivering initiatives on their behalf. However, a word of caution, even if you have an up-to-date DBS certificate: **you should never be left alone in a room with a child or group of children.**

Having a teacher or a guardian in the room with you at all times is a necessity, and guards against any potential claims of malpractice. Having a teacher present will also make it far easier for you to interact with children as they can help to introduce you and to control the environment, and can also work with you to deliver the initiative through careful co-design (see section 5.4.1).

The age of the children that you are working with will, to a large extent, determine the type of initiative that you develop and/or deliver. It is wrong to generalise and think that all teenagers are moody, and will have no interest or passion for science. However, some of them may have a negative attitude towards science because of a lack of engagement, poor teaching, or even previously ineffective science communication initiatives. In contrast, working with younger children can be a liberating and exhilarating experience. They are yet to develop the cynicism and awkwardness that can sometimes make engaging with older children so frustrating. Though be warned, the ebullience of this audience can also present problems in terms of behaviour and exhaustion. When working with any children, the same advice that was discussed in chapter 4 applies: do not attempt to patronise your audience; instead, ask them about

their needs and experience and develop/deliver your initiative accordingly. Carefully developed science communication initiatives can engage and empower children, instilling in them a love of science at this early and impressionable age.

Exercise: what does a child know?

It is easy to forget that as a scientist you know (and are surrounded by colleagues who know) a lot of information about your research, its related discipline(s), and science more generally. What you consider to be common knowledge might in reality be highly specialised information, especially to a child.

The next time that you have the opportunity to speak to a young child in an informal and supervised location, ask them what they know about science. Start off with questions that are quite general (What does a scientist do? What is physics?), and then begin to specialise (What is acceleration? What is gravity?). You will probably be surprised to find out what many children do (and do not) know, and you should use this to help structure your future science communication initiatives for this audience.

5.4.1 Children in a formal environment

The majority of science communication initiatives that involve children in a formal environment (i.e. the school classroom) can be classified as outreach (see section 5.2). The purpose of these initiatives is usually to engage with a group of schoolchildren about a particular area of science, to raise aspirations, and to re-normalise who scientists are and what they do (see chapter 9). However, rather than focusing on the children's supposed lack of knowledge, an approach based around the understanding of the learner(s) and the learning process should instead be considered.

Focussing engagement around the experiences and knowledge of schoolchildren involves a detailed understanding of the school curriculum, and an in-depth awareness of the needs and abilities of every child in the classroom. This is a lengthy process that cannot be fast-tracked, nor is there a need to do so when the children's teachers can provide this information. As such, it is advisable to involve a teacher in the development process as early as possible. Their knowledge of the curriculum and of general learning behaviours within the school environment will ensure that your initiatives are effective in engaging *their* students. They will also be able to provide constructive feedback with regards to what will (and will not) work in their teaching environments. Teachers should also be able to assist with basic logistics such as room setup, and will be able to ensure that the class is grouped (where necessary) to avoid disruption.

In instances when you have experience of successfully running a particular science communication initiative in a formal classroom environment, it is still good practice to engage with the teachers of any class prior to your delivery. It is wrong to assume that what works for one group of schoolchildren will work for another, and by providing a basic summary to the teacher beforehand, they will be able to give feedback as to what will and will not be engaging for their students.

Here are five further pieces of advice to consider when working with schoolchildren in a formal environment:

1. **The children are not your friends.** They are there to learn, and while they can have fun during the process, boundaries need to be established.
2. **Stick to time.** Schoolchildren will not thank you for eating into their breaks. For initiatives that take place in the afternoon, make sure that you finish with plenty of time to spare, as many of the children will have buses to catch or parents waiting to take them home.
3. **You know more science than they do.** A common fear of many scientists working in schools is that they will be 'caught out' on an area of science that they do not know. Ninety-nine times out of one hundred you will be able to answer any of the questions that you are asked. And for that one hundredth time, simply commend the questioner, and tell them that you will have to conduct some research before reporting back to them; alternatively, you could offer to work with the children to find out the question together. Admitting your lack of knowledge might also help to empower the teacher (who might not have a science background) when fielding difficult science questions from the children in the future.
4. **Expect the unexpected.** Be prepared to answer questions about your life as a scientist, and indeed your life in general. Young children in particular will be fascinated about what it is like to be a scientist, which exotic locations you have visited in your fieldwork, and how often you get to use robots.
5. **Don't get disheartened:** On occasions things will not go as planned. This may be for a number of reasons: the children, the facilities, the alignment of the planets, etc. Do not dwell on any negative experiences, instead reflect on what went wrong and how it can be used to improve future initiatives (see section 5.9 for a further discussion of reflection and evaluation).

Exercise: develop an outreach initiative for the classroom

Follow these steps and devise an initiative to discuss your research with schoolchildren in a formal learning environment:

1. What is your objective? Do you want to raise awareness of a particular subject? Introduce the class to a famous scientist? Better understand what they know about particle physics?
2. What format is most suitable for achieving your objective with this audience? Is it via a short presentation, a series of demonstrations, some hands-on experiments, or something more creative?
3. How does this tie in to the school curriculum? Your initiative will be more effective if the topics that you are covering can be linked to the curriculum. This is especially true for more mature schoolchildren, where classroom time is often on a tight schedule.
4. Run your ideas past a teacher. They will be able to advise what will and will not work in their classroom, and will also be able to help with linking your plans to the taught curriculum.

5. Beta-test your initiative. Aim to have at least a couple of dry runs before taking the initiative into a school, as this will help you to iron out any issues beforehand. Undergraduate and postgraduate students are great for helping at this stage.
6. Trial your initiative. Get in contact with the teacher that you spoke to in the development process, and see if they are willing to let you try out your initiative in their class.
7. Reflect on the trial. What went wrong and what went right? Ask for feedback from the teacher and their class (see section 5.9), and also from the people that were involved in the beta-testing process. How can you use this feedback to improve your initiative, and do you need any further support and/or resources to better implement it?

5.4.2 Children in an informal environment

Learning does not just take place in the classroom. There are many different environments outside of school where children can continue to learn about science in a more informal setting, including: museums, science centres, and even zoos. However, informal science education is not just defined by learning that takes place outside of the classroom, but rather as something that is self-motivated and guided by the learner's needs and interests [18].

Large science initiatives for children often take place in these informal settings, and include science festivals, science fairs, and public lectures. For example, the Royal Institution Christmas Lectures in the UK have been running since 1825 and are aimed at a mainly teenage audience, taking place at the Royal Institution in London each year [19]. Informal science communication initiatives such as these have been shown to foster a strong commitment to science and science learning, and to have a strong impact on future career choices [20].

When running an initiative in an informal environment that is aimed primarily at schoolchildren, take account of the following:

1. A teacher might not accompany the children; instead a guardian might be present, or they may be unattended. In any case, the children will behave differently outside of the school environment. They may feel less awkward, but similarly there may be behavioural issues that need to be kept in check without the presence of a teacher. In these informal environments it is just as imperative that you are never left alone with any children.
2. If your initiative is not part of a larger science festival, or is alongside other initiatives that are not science-themed, then your participants may not be expecting to do any science. These 'science by stealth' opportunities [21] are an effective way of reaching new audiences, that might not otherwise seek out science-specific initiatives.
3. There might be a larger or a smaller influx of people than you were expecting. Plan for both eventualities, especially when arranging the number of scientists that will be involved. Where possible, have several activities that are flexible in the number of people they involve and the time they take to run; doing so will mean that you can engage both small and large audiences accordingly.

5.5 Different formats

Just as there are a diverse range of publics, there are also a large variety of formats that can be used to achieve your objectives and engage your target audience. In this section several different formats, and the practicalities for running these, are discussed. While this is by no means an exhaustive list, the formats presented here have been chosen to demonstrate the wide variety that is available.

Some of the formats discussed below might be considered to be examples of outreach (one-way communication), some are public engagement (two-way communication), and some have the flexibility to be both. Over the past couple of decades, research in the field of science communication has generally tended to recommend public engagement formats as being more effective than outreach in engaging different publics [4]. This is largely because outreach is often associated with a deficit model of engagement, which has in turn been heavily criticised as being ineffectual, oversimplified, and derisory, in assuming that non-scientists are 'deficient' and scientists are 'sufficient' in knowledge [22]. However, while meaningful dialogue over science-related issues is essential for the development of science, and society more generally, providing reliable information in an accessible way is often an essential prerequisite for this to occur [23]. Furthermore, a gain in knowledge can have positive impacts on people's attitudes depending on their contexts and pre-knowledge [22]. If done correctly, outreach initiatives that are one-directional in format can still be extremely effective in achieving objectives and engaging audiences. We need only look at the impact that nature documentaries, such as the *Blue Planet* series hosted by David Attenborough, have had to see evidence of this [24].

The following introduction to these selected formats should help you to think about how to develop your own science communication initiative, with both your objectives and your audience in mind. Section 5.11 provides examples of some successful science communication initiatives that have made use of some of these formats.

Science talks

The most standard form of outreach is a science talk. This may consist of a lecture-style talk with an accompanying Q&A session, or a more informal discussion such as those hosted by a Café Scientifique [25]. Whatever the setting, the advice provided in chapter 4 still applies: consider your narrative, your audience, and yourself. Also, just because you are not speaking at an international scientific conference, do not assume that there are no experts in the room. Instead, try to find out who your audience will be, so that you can avoid either overestimating their knowledge or underestimating their intelligence. The advice that was given in chapter 4 with regards to preparation is also appropriate here: find out what AV equipment is available, and try to arrange a practice session or sound check in advance if possible.

Panel discussion

A panel discussion is an effective way of showcasing a variety of different opinions and knowledge surrounding a certain topic. They also help to demonstrate to the audience that science is a varied and much-debated topic, in which there are sometimes quite

fierce and contrasting views. If taking part in a panel discussion, find out in advance about the format (round table, open Q&A, short presentations, etc) and also your fellow panellists, and their attitudes regarding the topic(s). If you are organising a panel discussion then choose a topic that is relevant to the intended audience, and invite a diverse selection of panellists (not just scientists), who can represent different points of view. If you are recording the panel discussion then get explicit permission from the panellists, and ensure that they are aware of how it will be shared (e.g. streamed via social media, or hosted on an institution's webpage). Picking a chairperson who can both keep to time and ensure that all voices are heard is also essential.

Science busking

Science busking involves capturing people's attention in a public space using the 'magic of science'. For example, you might make a cloud using only a bottle of water and a lit match, or demonstrate surface properties by putting a wooden kebab stick through a balloon without it bursting. When done properly, this can be an effective, enchanting, and innovative way of engaging a potentially large group of people. Like other forms of street performance, there is a definite skill in engaging an audience, and inspiring people to want to approach you to ask questions. If you are interested in finding out more about science busking, then Science Made Simple and the British Science Association have created a useful resource, which includes a selection of science busking activities that are suitable for all audiences [26].

Book clubs

Setting up and hosting a book club provides an innovative way of discussing science in an accessible and engaging format. If you plan on running a book club then it helps to have an overarching theme that is not too broad; for example, books that involve 'time travel,' rather than 'science' in general. Meeting once a month will give people enough time to read the selected title, and choosing books that are readily available from local libraries will help to keep the costs down. It is also recommended that you plan out a number of books in advance, and that each member of the group gets the opportunity to select a book as well as to take part in the discussions. You might also consider setting up a digital book club, in which members meet on social media (Twitter is ideal for this) at an allotted time. If you take this approach, then account for different time zones if you want to include a more diverse audience.

Workshops

We are using the term workshop here as a catch-all term that involves working with an audience in order to discuss and deliberate a specific topic of interest. This might be a one-hour meeting over tea and biscuits in a local community centre in which participants are invited to chat to scientists about their knowledge of the solar system, or a series of initiatives in which scientists and non-scientists are asked to brainstorm ideas for future clean energy solutions to present to local policymakers. Whatever the format of your workshop, they should have a clear objective, and be framed for a specific audience; they should also be conducted in a way which enables the participants to feel safe, and where all voices can be heard and respected.

Citizens' juries

A citizens' jury is a special type of workshop; a specific method of deliberation in which a small group of people (typically 10 to 20) come together to discuss a well-framed question or issue, over a time period of two to seven days. The jury members are selected to be representative of the target audience, and the aim of the jury is to allow non-scientists to meaningfully discuss, in detail, a topic that tends to be either controversial or of deep societal significance. Developing and delivering a citizen's jury is not something that should be taken lightly, as they require large amounts of resources, in terms of both time and money. However, they can create a platform which genuinely involves the participants, granting them ownership and agency of the process. Involve, the UK's leading public participation charity, have a large variety of resources that can help you to plan a citizens' jury, including detailed explanations of suitable methods and successful case studies to draw from [16].

Whatever format you decide upon, it is vital that you consider the ethical implications of your initiative. If you are planning on conducting any research, or carrying out an evaluation which involves collecting personal data from the participants (see section 5.9), then you should seek ethical clearance from your research institute. Even if you are not collecting any data from the participants you should still think carefully about the repercussions of your proposed format. For

example, if you are talking to a group of elderly people about the latest medical research on dementia, then be sensitive to the effect that this may have on some of the audience members. Similarly, if you are planning on discussing anything that others might perceive to be upsetting or offensive, then signpost this with appropriate trigger warnings. Developing your science communication initiative with members of your intended audience will help you to identify when and where such incidents may occur.

5.6 Citizen science

Citizen science is a popular example of a public engagement format. In essence it is a type of collaborative research that involves members of society (or citizens) in actively collecting, generating, and in some instances analysing data.

There are many examples of citizen science projects, but one of the most well-known is Galaxy Zoo [27], an online series of projects which invites participants to classify different types of galaxies according to their structure; the human eye being better equipped at making these distinctions than a machine. There have been many versions of Galaxy Zoo, with Galaxy Zoo 1 (which ran from 2007 to 2009) receiving more than 50 million classifications from over 150 000 people in just year one of the project.

Another popular citizen science project is Old Weather [28], which aims to help scientists recover weather observations made by US ships since the mid-19th century, by enlisting citizens to digitalise old transcriptions recorded in ship logbooks. Such information ultimately improves the collective knowledge of past environmental conditions, with a better understanding of these past occurrences leading to an improvement in modelling future weather patterns.

There are also a number of citizen science programmes that actively source data directly from members of the public. For example, the Community Collaborative Rain, Hail & Snow Network [29] is a non-profit, community-based network of volunteers who measure and map precipitation using low-cost measurement tools with an interactive website. The project started in Colorado in 1998 and now has networks across the United States and Canada, involving thousands of volunteers, and making it the largest provider of daily precipitation observation in North America.

The main objection to these types of citizen science projects are that they are potentially tantamount to free labour, with scientists relying on non-scientists to collect and/or analyse vast swaths of data. While there are many incentives for performing these tasks (such as prizes, badges, and general kudos), it tends not to be the citizens whose names appear on the associated research publications and/or grant applications.

If you are thinking of developing a citizen science initiative then make sure that the citizens you recruit are properly recognised, and where possible involved throughout the whole process. As an example, the UK Community Rain Network, in which children from across the UK monitored precipitation using

home-made rain gauges, acknowledged all of the participating citizens in the subsequent journal publication [30].

Overall, citizen science projects are becoming an increasingly popular means by which to engage the public, while also benefiting scientific research, especially given the growing ubiquity of social media and other communications platforms (see chapter 7). However, there is a need to actively involve the participants in these projects, and to ensure that they receive the appropriate acknowledgements; otherwise scientists run the risk of treating their new colleagues as nothing more than second-class citizens.

If you are interested in setting up your own citizen science project, then the Natural Environmental Research Council and the Natural History Museum have produced a very useful guide on how to do this both effectively and ethically [31].