
Towards a professional development framework for scientists involved in public engagement work

Final Report

Prepared for: Wellcome Trust Sanger Institute

Prepared by: Alison MacLeod, The Human Element

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Introduction to the report

This document reports on the research, design and initial testing of a framework for improving professional development in science communication.

The first part (sections 1 to 6) was originally written in December 2008. It looks at science communication skills and how they develop. It provides a review of relevant literature, an analysis of current science communication training practices, and an outline of training models used in three different occupations. Based on this analysis, I recommended a preliminary model of skills development that would apply to science communication as practised at the Sanger Institute.

The ideas presented in the first part of the document were debated with the Public Engagement team, and then tested in science communication training. The final section of the report presents a revised version of the development framework, informed by the piloting process. This section was originally written in April 2009, well before the current mushrooming of interest in professional development.

In the light of the keen interest shown by a number of bodies, it was decided to make this combined report publicly available.

For external readers, there is one important caveat: the frameworks developed here were intended for use in a very specific context, that of the Wellcome Trust Sanger institute. It is likely that other organisations might have somewhat different needs.

This document would not be possible without many long discussions with the Public Engagement team (Bronwyn Terrill and Chris Stock). I would also like to thank all the scientists who tested out the training with us, and who were so willing to try out completely new skills.

Alison MacLeod
The Human Element

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1. The context

1.1 Public Engagement at the Wellcome Trust Sanger Institute

Public engagement has been part of the Wellcome Trust Sanger Institute for many years. Initially, the focus was on explaining the industrial-scale science processes of the Human Genome Project. Now that the genome has been sequenced, there is less emphasis on understanding sequencing and more emphasis on understanding the genomics research being undertaken.

The Public Engagement function is a [small, growing team of specialists](#). The team hosts groups of school pupils ('A' level and GCSE), teachers, visiting scientists, and interested adults. Site tours and talks for visitors are provided with the help of working scientists. The Public Engagement team see it as their role to involve, support and develop scientists to undertake this role.

Public engagement as an activity is well supported within the organisation, with scientists being encouraged to participate in public engagement activities as part of their overall development. While much of this work involves internal tours and talks, there are also opportunities for scientists to get involved in external talks, writing, science week activities and other collaborations with artists, media producers, museums and science centres. In the future, the Public Engagement team would like to develop scientists' abilities to engage with audiences on more complex topics.

Current training for young scientists involves two half-day workshops on public engagement. Scientists are recruited to the programme through a mixture of routes, including approaches by the scientist or their supervisor, and attendance at general information sessions hosted by the public engagement team. Training and development is low-key, with scientists encouraged to become involved, and provided with informal feedback and support from the Public Engagement team.

The Public Engagement team were interested in taking this work a stage further, and defining public engagement skill levels in more detail. This would enable the team to describe the public engagement skills and experience of individual scientists more fully than is possible at the moment, and provide a general indication of an individual's level of skill. The ideal would be to develop and design a general model of professional competence in public engagement work, which could be applied in the context of the Sanger Institute.

1.2 Requirements for a framework

In order to develop such a framework, we would need to know:

- The kinds of skills and abilities science communicators need in order to become more effective practitioners
- How these skills develop naturally over time, especially in early practice
- What developmental stages practitioners go through, in evolving their practice, and how skills are best fostered
- How this general learning can best be applied to the Sanger Institute context

The final framework should satisfy certain conditions:

- Relevant to public engagement work as practised at the Sanger Institute
- Supporting Public Engagement values promoted by the Wellcome Trust
- Primarily concerned with objective knowledge and observable behaviour (although subjective feelings may also be relevant)
- A practical means of assessing skills among scientists working in the area
- Capable of being developed into a self-completion checklist, questionnaire, or set of assessment guidelines for a supervisor/observer
- (And implicitly) Acceptable both to the scientists and the Public Engagement team.

1.3 Some observations on the review

In early discussions, the task seemed fairly straightforward: conduct a review of the literature, discuss findings and then propose a development framework.

The initial guess at an eventual framework was something quite staircase-like, with each carefully-defined step on the staircase corresponding to a different stage of development. The advantage of such a concrete approach is that it would give the Public Engagement team information about people's current skills and abilities, and it would also provide the individual scientist with clear targets for developing their own skills.

Unfortunately, the world of science communication did not, in the end, lend itself to this straightforward vision. As it turns out, the amount of directly relevant literature on science communication skills was very limited. There was no pre-existing model of skills development to draw on. Furthermore, the task was complicated by the fact that the practice of science communication at the Sanger Institute is not the same as either science communication as practised in science centres and museums, or indeed science communication as general engagement with the public: it needed its own, specifically tailored approach.

However, while there were no easy answers within the science communication literature, there was plenty of insight available from other fields, and the document has drew on these to frame a discussion of what early professional development in science communication could look like.

Part One is broken into several sections. The first section provides an overview of our current understanding of how complex skills are acquired in careers, and proposes an initial developmental model for thinking about professional development.

The second section of the report looks at the content of current UK training and career development in science communication, and supplements this review with a number of case studies from other occupations.

The third section applies this knowledge to the Sanger Institute context, discussing issues and operating constraints, providing an initial list of skills, and proposing a framework for professional development.

2 Skills development during careers

2.1 Introduction to the literature review

Note: this review was conducted in late 2008.

The first thing that has to be said about this area is that the amount of traditional research literature specifically related to professional skills development in science communication was very small indeed. There are a handful of papers that deal with the topic directly, and there is clearly some discussion of professional development taking place at science communication conferences. Communication skills themselves are the focus of certain policy reviews and indeed funding initiatives such as the *Beacons for Engagement* project. However, while skills development is generally seen as important in science communication, the content of those skills is rarely discussed in detail.

Since directly relevant literature is hard to find, this review draws on general literature on the development of expert performance, as well as literature relating to professional development in several analogous fields.

2.2 Outside perspectives on developing expert skills

The journey to expertise

While the science communication community does not really have a model of development for those new to the field, there are plenty of helpful perspectives available from work on the development of complex skills in different domains. Several specific domains are discussed in detail later in this report. However, before looking at specifics, it is useful to look at career and skills development in general, and see what can be applied in the area of science communication.

The earliest models of complex skill acquisition see professional development as emerging from long apprenticeship spent with a master. Calman (2007), in his review of medical education throughout history, describes apprenticeship models from early Chinese medicine. In one ancient Chinese system, it took nine years for a novice to become a physician – three years for the master to choose the disciple, three years for the disciple to evaluate the master, and three further years for the master to transmit his knowledge. Ancient Greece had similar practices, with craft knowledge (*techne*) being passed on from teacher to pupil.

These ancient apprenticeships had very similar features in common – the close relationship between master and pupil; the individual and personalised approach to learning; and the extensive time to learn and refine practice. Although we tend to think of much modern development as rather standardised and brief, there are still plenty of occupations, particularly the professions, which require long training and apprenticeship prior to fully independent practice.

Mediaeval craft guilds divided the journey from novice to master into a series of distinct stages: a beginning as initiate or novice; then a long apprenticeship to a master, followed by a period of independent practice as a journeyman (a craftsman who travelled around building up his expertise). Eventually the journeyman was elevated to master craftsman status, after successfully producing ‘master pieces’ intended to showcase the maker’s mature talents (Hoffman and Lintern, 1998). As with the ancient master-pupil relationships, we have the phases of learning and initial qualification, early independent practice, and maturation into assured expert. These early models also have the notions of personal feedback, observation and critique built in.

Mastery in many fields still takes a long time to be achieved. Studies of modern experts in fields such as air traffic control, competitive chess and classical music performance show that the attainment of expertise requires extensive, deliberate practice. As a rule of thumb, at least 9-10 years or 10,000 hours of deliberate practice underpins the mastery of experts (Eriksson, 2006).

Practice alone does not confer mastery. Studies comparing expert knowledge and behaviour with that of less experienced people in the same field find that the experts are able to organise their knowledge very differently to novices. As a simple example, chess masters are able to draw on a much bigger set of strategic choices, compared to ordinary players, and they are able to think far more strategically. Experts are able to synthesise their knowledge and apply it in an informed, skilled way to new situations. Experts in medicine, for example, draw on better understanding of underlying mechanisms, better mental representations of diagnostic problems, and (obviously) previous experience of many examples (Eriksson, 2006).

Defining knowledge and skills

In trying to understand how people’s expertise develops over time, it soon becomes important to try to break down individual elements of that expertise. In the medical domain, Norman et al (2006) describe three types of knowledge that are thought to be vital to the development of medical expertise: causal knowledge (basic biological processes), analytical knowledge (signs, symptoms and diagnoses) and experiential knowledge (exposure to many different cases through working experience).

This three-part conceptualisation of job expertise is a popular way of classifying skills in a range of occupational domains. For example, Voss and Wiley (2008), examining the expertise of historians, also divide historians’ knowledge into three parts: skill in obtaining information; in analysing historical narratives; and general reasoning and problem-solving. Fish and Coles (2005) divide skilled medical practice into knowing, acting and thinking: teaching typically differentiates between subject knowledge, pedagogical knowledge, and skilled practice.

Occupational psychology has traditionally tended to define the requirements of any given job role in terms of ‘KSAs’ – the knowledge, skills and abilities required to perform the job (Goldstein and Ford, 2002). This approach to defining jobs has been seen as too basic and atomistic for describing complex professional occupations (Fish and Coles, 2005). The word

‘skill’ has also become somewhat devalued, in much the same way as ‘apprenticeship’ has come to be applied to manual occupations rather than white-collar or professional ones.

In the realm of management, the concept of KSAs has been somewhat overtaken by the idea of ‘competency’, an approach popularised by the influential psychologist McClelland, and built into an entire scoring system by the Hay/McBer consulting group (who developed a system for assessing what were described as ‘core competencies’).

The concept of competency is somewhat politically fraught: the word is used (and spelled) in a number of different ways. Sometimes it is used to refer to behaviour and sometimes to refer to underlying personal characteristics (Williams, 2002). While the competency approach is very popular amongst consultants, its many confusing definitions mean that it is less well supported by occupational psychologists.

The greatest strength of the competency approach may be the rigour of the method, rather than the theory. The competency approach begins by defining individual skills or competencies, with reference to the qualities of an excellent performer on the job, and then broken down into levels of performance.

Here is an extract from the detailed definition of a single competency, ‘Developing others’ taken from McBer’s ‘core competency’ framework (Hay Group 1996). The first three of five total levels of performance on this attribute are quoted. Each level is carefully defined and described in terms of behaviour and attitudes.

Developing others: Involves a genuine intent to foster the long-term learning or development of others with an appropriate level of need analysis and other thought or effort. Its focus is on the development intent and effect rather than on a formal role of training.	
Level	This person
1	Expresses positive expectations of person. Makes positive comments regarding others’ developmental future, current and expected future abilities and/or potential to learn, even in difficult cases.
2	Gives how-to directions. Gives detailed instructions and/or on-the-job demonstrations, tells how to do the task, and makes specific, helpful suggestions.
3	Gives reasons, other support. Gives directions or demonstrations with reasons or rationale as a training strategy. Gives practical support or assistance to make job easier for subordinate (i.e. volunteers additional resources, tools, information, expert advice etc). Asks questions, gives tests or uses other methods to verify that others have understood explanation or directions.

The McBer framework has been enormously popular in management, and as discussed later in this document, it is broadly the approach used in medicine. Teaching, on the other hand, uses a KSA framework, grouping important individual attributes (which resemble competencies) under KSA-style headings. There are plenty of similarities between the two approaches.

As used in management, the concept of competency has come to refer to more personal, abstract attributes required to do well within the job, such as the ability to plan projects carefully, or an attitude of being sales-oriented (Williams, 2002).

However, while it may be helpful to define desired performance in these more abstract terms, translating these into training still tends to require more concrete analysis of exactly what good performance should look like (Goldstein and Ford, 2002) – in other words, an analysis of the knowledge, skills and attributes required to do the job. Critics of the competency approach, including the medical educators Fish and Coles (2005), take issue with the language and the possibility of confusing ‘competency’ (ability) with competence (good, safe performance).

Whatever the term used, it is vital that the competencies/KSAs are defined well, with reference to the actual knowledge and qualities that good performers possess. At present, our analysis of the skills needed for good science communication is somewhat limited, and has not been tested against actual practice.

Training and development in occupations

Occupations vary widely in terms of the training and development required of newcomers, and the ways in which this is acquired. Certain occupations such as medicine, teaching and the police service involve strictly controlled entry, extended training, and an assessment of competence. There is professionalism, in terms of values and professional standards required, and also in terms of compliance to a regulatory regime in which continuing professional development may be mandatory rather than voluntary.

Other occupations, including many in modern white-collar occupations, are far more loosely defined and controlled, and training is undertaken to meet development needs rather than being a closely guarded point of entry. Training philosophy and training effectiveness tend to have been studied more closely in highly regulated occupations.

Academic science is not protected in the same ways as many professions. The high barriers to entry and progression mean that it probably functions as a ‘tournament’ career, where individuals compete for elevation to the next level (Rosenbaum, 1989).

Goldstein and Ford (2002) list five types of general training that are common in white-collar occupations: structured on-the-job training (for example, new recruits to call centre work); unstructured on-the-job training (occasionally referred to as ‘Sitting by Nellie’); apprenticeship; embedded training, where training is incorporated into work; and self-directed learning, where employees (typically at managerial level) take responsibility for their own professional development. The effectiveness of training is less extensively studied in these types of occupations: however, Goldstein and Ford suggest that structured training, whatever the context, tends to result in better performance, providing that the training is relevant and high quality.

Short training courses, of the type offered to Sanger Institute scientists, vary hugely in their effectiveness, for many reasons. One reason for ineffectiveness is the opportunity and support to practise new skills (Salas and Cannon-Bowers, 2001). If the training is not applied in a real context soon after training, the benefits are easily lost.

Other types of training, once employees are familiar with the basics of the job, may include training aimed at developing teams rather than individuals. Various approaches to team training include cross-training (where individuals within a team are taught how to do one another's jobs), adventure learning (outward bound courses and the like), and action learning (Goldstein and Ford, 2002). Action learning is a training/learning paradigm widely used within the public sector, including teaching, to describe developmental projects that teams tackle together. Typically, the action learning team defines the problem, finds resources, searches for evidence and undertakes small-scale projects or changes. Action learning is also popular in public engagement work.

Learning processes

What are the processes at work when people learn during training, either on the job or off it? Observation of an expert at work allows a trainee to see real behaviour in action. Bandura's theory of social learning (see Bandura, 2004, for an overview) proposes that individuals learn behaviour, whether positive or negative, by watching other people interact. Bandura developed these ideas further into a behavioural therapy method, guided mastery modelling, where people such as phobics gradually learn to overcome their fears by watching someone else engage with the feared object.

However, learning effectively from an expert may involve more than simply observation. Novices may fail to note important elements in what they are observing. Bransford et al. (2000) showed that when novice and expert teachers view the same videotape of a class session, experts see the scene very differently. They notice far more than the novices, and they have the language and concepts to articulate what they are seeing.

Equally, Hoffman and Lintern (2006) suggest that experts may find it difficult to articulate their knowledge to teach non-experts. This is not necessarily because their knowledge is tacit, but because expert rules and schemas may not emerge in simple questioning (Salas et al., 1999).

The successful transmission of skill, then, from an expert to novice, may not simply be achieved by the novice observing and the expert questioning and elaborating. This master-pupil approach was the commonest method of teaching clinical skills in medicine. In recent years, the medical profession realised that relying on senior consultants was not good enough to produce the best, most effective type of clinical practice. While senior supervision remains an important element, there is now far more emphasis on developing effective teaching skills amongst clinicians and developing effective learning strategies for doctors (Fish and Coles, 2005).

The acknowledgement of effective teaching as involving pedagogical knowledge as well as subject knowledge is new to medicine. Calman (2007) quotes an anecdote about a GP who

accompanies a highly successful medical man on his rounds, and eventually asks the expert what his secret was.

‘Unfortunately Dr Briggs was quite unable to impart or hand on his secret. He didn’t know how he knew. His experience was entirely personal to himself.’

Calman uses this anecdote as part of his argument for developing more effective methods of teaching medicine. While experts are excellent performers, they may be clueless when it comes to transmitting their own knowledge effectively to other people. Teaching other people requires specific teaching skill, as well as experience and subject knowledge.

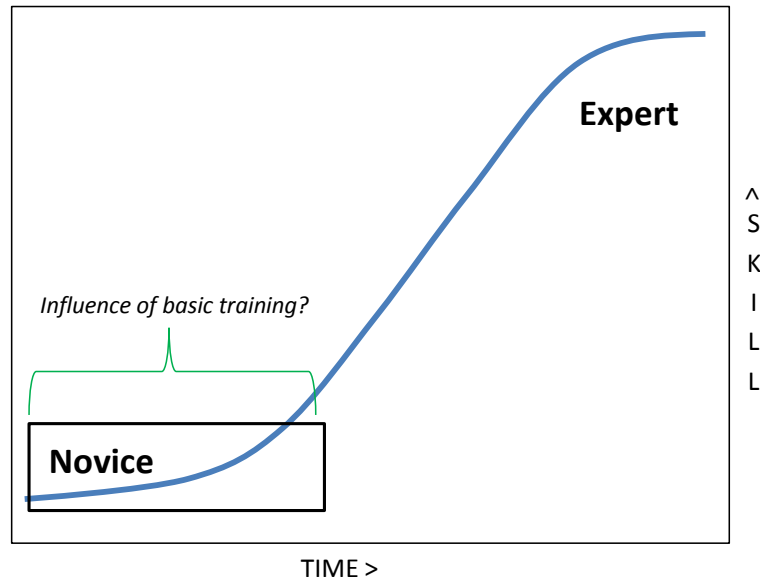
2.3 Applying theory to the Sanger Institute context

The journey from novice to expert in a given field is conceptualised in the diagram below. The X axis shows time and the Y axis shows level of skill. Over time, general expertise rises to its maximum. In the example here, expertise reaches an asymptotic level, which may apply to some fields but not others

The research on expert performance suggests that expert level is reached after about 10 years of sustained practice. This length of time may not apply to a field like public engagement, but even if we considerably scale back the amount of time estimated, we are looking at a substantial slug of time relative to the kind of time that a scientist is likely to spend communicating science as an occasional, sideline activity.

So, if the graph below shows the lifetime development of a full-time expert, then the inset box shows the much smaller amount of time and development that may apply to science communication when practised (and taught) as a sideline to someone’s main career.

The journey to expertise



The journey from novice to expert here is represented by a smooth s-shaped curve. This is a vast oversimplification, and the shape of the line has no particular significance.

What do we actually know about the specific journey within science communication work?
The next section explores what we know from current practice.

3. Science communication training and development in the UK

3.1 Science communication as a career or skill

Involvement in science communication in the UK takes one of a number of different patterns. There are at least five main patterns:

1. Professional science communicators
2. Academic science communication experts (who may also be involved in science communication)
3. Science popularisers, who become popular with the public through writing, lecturing, journalism, or broadcasting
4. Science defenders, whose work is important or controversial, and who seek to explain their work
5. Scientists involved with science communication in schools or science events, as a sideline to their main work.

The professional practitioners (science communicators) may work for research councils, in science centres and in museums. Some specialists in this group will rely on constantly finding further grant funding for their work.

Science communication in the UK remains a rather fragmented line of work, with no real career path. As such, it is not protected or professionalised, and to some extent, professional development in the field seems barely considered as a topic. Searches of Psi-Com (science communication database) and the Wellcome Library catalogues found a handful of references that dealt with the subject.

Selkirk (2001), reporting on the future market for science communication courses in Scotland, characterised science communication as:

‘A young profession, without a recognised career structure and (...) thus far, a poorly-paid profession.’

A recent biography piece on a Biocareers website by a young science communicator, Leigh Fish¹ demonstrates both the youth and the financial uncertainty of some science communication careers:

Q Do you have any advice for people thinking of a career in science communication?

A This can be a very difficult field to get in to and it is sometimes necessary to take low paid or voluntary jobs just to get experience. The pay in science centres is relatively low (even with a higher degree and 5 years experience), and job security is rare. However, everyone in this field is committed, not in it for the money, and generally has a high level of job satisfaction (for as long as the post lasts) - it's a lifestyle choice.

The second type of science communication expert is the academic specialist, who may have a background in science or social science. These are the academics who conduct their own research and run master's degree courses on science and society. Although there is some crossover between the groups (some academic experts are extensively involved in science communication), theory and practice tend to involve different groups of people.

Hanssen et al. (2004) commented on a lack of training for science communication practitioners in the Netherlands, and a continuing gap between science communication practitioners and science communication academics. They characterised science communication practice as unconcerned with effectiveness, with:

'...a lack of professional self-reflection among its practitioners and failure to use a theoretical model to substantiate choices.'

Gregory and Lock (2008) in a piece considering the evolution of the public understanding of science (PUS) field in the UK, also commented on the divide between practitioners and academics. Gregory and Lock suggested that working scientists will tend to ally themselves with practitioners, rather than public understanding of science academics, because academics typically use the language and theoretical frameworks of social science.

Science communicators and science communication academics may also have quite different terms of reference. Science communication is usually quite focused and circumscribed (talking about a specific subject to a specific audience), whereas academic activity appears to focus on the analysis of science media coverage and science understanding. This kind of academic analysis may find practical applications by influencing public policy or research council policy, rather than affecting individual science communication practice. A brief inspection of the last 3 years' content of the two main journals specialising in science communication (*Science Communication* and *Public Understanding of Science*) shows that the main content is analysis of 'controversial' science debates, or research on audience perceptions. There appears to be a limited amount of content that would be specifically relevant to everyday practice, and virtually nothing on professional development.

Mesure (2007), presenting the results of the Crescendo project, which aimed to build more effective networks between practitioners in the UK, discusses some fundamental structural barriers to building professional skills in the area. He suggested that funding patterns for science communication work, where groups typically receive short-term funding for projects from competitive grants schemes, help create a situation where practitioners' spare energy is taken up by finding further funding, and practitioners view their work as rather personal work which is not necessarily shared or disseminated. He looked to the creation of *Beacons for Public Engagement* (HEFCE and the Wellcome Trust, 2006; see later discussion) as a structure that would support longer-term development in science communication.

There are also scientists who are heavily involved in public engagement but who are likely to define themselves as scientists first and foremost: these individuals are typically senior scientists, who have become involved in public engagement either to enthuse new audiences

(for example, via the Reith lectures) or because their area of scientific expertise is controversial or newsworthy. In terms of training, these senior scientists are likely to be either self-taught, or to have had media training, to help them talk to journalists and express their ideas effectively.

The final group is the working scientist who, like the Sanger Institute scientists, wants to ‘put something back’ by explaining their work either to the general public or to students and school pupils. These scientists are offered some support from research councils, grants and schemes such as Beacons for Public Engagement. Details of what is offered to this group are discussed in the next section.

3.2 Training in UK science communication

(Note: this overview was correct at the time of writing, in December 2008, but the picture has changed since then).

Public engagement skills are taught formally in two contrasting ways: via postgraduate courses, and in short 1-2 day courses. There are around 10-12 postgraduate courses and two undergraduate courses in the UK which focus on science communication or science and society.

Undergraduate degrees

At the time of writing² the University of East Anglia and the University of Manchester offer undergraduate courses in science communication combined with biology. University College, London offers a B.Sc in science communication and policy, plus a number of options combining this subject with a modern foreign language.

A number of universities (such as University College, London) also offer science communication as an undergraduate module.

Master’s degrees

There are approximately 10 courses focused on science communication or science and society, and a further 3-4 that focus on journalism. The British Council offers a list of current master’s degrees³, as does the British Association⁴. The Intute database has a longer list that includes writing and journalism courses⁵

The M.Sc. courses differ in their detailed design, but cover broadly similar territory, including understanding audiences and understanding how the media report science stories. Some of the master’s degrees offer practical experience, for example in developing a museum exhibit or writing a science story. The University of the West of England, has a course which is weighted towards the development of practical skills in science communication⁶. (It is intriguing to see that one of the UWE course modules ‘Science Direct in Practice’ is actually aimed at developing grant-writing skills).

The University of Glamorgan's 'Communicating Science' course⁷ also has a practical orientation. In contrast, University College London (which runs lots of modules and courses in the area) has a heavyweight academic focus.

Most of the master's degrees offer a viewpoint that is steeped in contemporary social science. They may prepare students either for further research and academic study, or for working in science communication and public engagement. Essentially, however, these are qualifications that are sought out by people who want to specialise in science communication full time. The majority of Sanger Institute staff who become involved in public engagement will expect this kind of work to be an add-on to their daily work as scientists, not an alternative career.

Short courses

The Wolfendale Report (1995)⁸ recommended that scientists and engineers should receive training in how to communicate their work effectively to the public, and suggested that science communication training should be included as a component of undergraduate degrees and postgraduate degrees. This formal acknowledgement of the importance of basic communication skills has continued to be part of the UK research councils' policies.

Still, a joint report from the Royal Society, RCUK and the Wellcome Trust, (2006)⁹ suggested that 73% of scientists had not received any training on science communication or public engagement, and like the Wolfendale report before it, emphasised the importance of providing scientists with specific communication skills training.

More than a decade on from the Wolfendale report, the main form of training in science communication remains the short one or two-day course. These are run by most of the research councils involved in science funding, and they are aimed at PhD students, postgraduates and working scientists. For postdoctoral scientists, these types of courses tend to focus on improving skills in communicating science to the public, or dealing effectively with media contact. While it is clearly an achievement that public engagement skills have been embedded into continuing professional development for scientists, this provision does not really go beyond basic, introductory levels.

Other approaches

There appears to be very little structured training available in the UK between short training courses and extended courses leading to formal qualifications, at least for scientists. However, there are a number of more individual awards and initiatives aimed at encouraging scientists who want to enrich their public engagement work. Some of these offer quite innovative approaches to professional development. The British Council maintains a list of these¹⁰ which at the time of writing included the following courses:

- **Science and Engineering Ambassadors Programme**
Run by the Science, Engineering, Technology and Mathematics Network (SETNET). The Ambassadors are scientists and engineers working in industry, who volunteer to work with schools and enthuse them about science. There are currently 18,000 Ambassadors in the UK. The scheme is administered through regional bases which win contracts to

deliver (to quote the Cambridgeshire group) ‘brokerage of Enhancement and Enrichment (E&E) to all schools and colleges for Cambridgeshire.’¹¹ The STEMNET website¹² (and indeed the regional sites) are extremely vague about what exactly ambassadors do or how they are supported, but it appears that their main function is to be role models from industry, offering talks and tasters to school pupils.

- **The Researcher in Residence** schemes place a scientist in a school (Wellcome Trust and Research Councils UK, along with a consortium of providers, mostly based in universities) for a total time of 12-24 contact hours. The scheme seems to be aimed at PhD students and young researchers, and there is a clear path of entry to the scheme. At the time of writing, this scheme seems to be starting up, recruiting researchers and launching partnerships. Researchers are supported through short training/briefing days and encouraged to plan, consult and evaluate with their teacher partner.
- **Partnership Grants Scheme** (Royal Society) provide small-scale funding for scientists and schools to work on projects together. From the numbers quoted, it appears that between 30-40 grants are awarded each year. Scientists and teachers apply for funding together.
- **British Association Media Fellowships** These provide placements of three to eight weeks working with a UK press, broadcast or internet journalist. Ten media fellowships were given out in 2008.
- **Beacons for public engagement**¹³ (RCUK and the Wellcome Trust) are six ‘university-based collaborative schemes’, plus a central co-ordinating groups, launching various public engagement initiatives. One role of the National Co-ordinating Centre¹⁴ is to ‘help professionalise’ university engagement with the public.

‘The National Co-ordinating Centre for Public Engagement will provide leadership and will work with the beacons, funders, policy-makers, and the whole HE sector to make engaging with the public a key part of what it is to be an academic.’

The central co-ordinating group aims to professionalise, by providing talks and workshops, and online networks; and by developing ‘a simple framework that pins down the basics’ and ‘a charter that challenges Universities to change how they work and to embed Public Engagement in their mission.’ The parties which make up the co-ordinating centre are all highly experienced science communication specialists.

The Eastern Region beacon, based at the University of East Anglia, offers 1-day training for scientists new to public engagement, to help them think, plan and evaluate their activities. Scientists are also offered a mentor. Other supporting activities, under the umbrella of continuing professional development for academic staff, offer talks and sessions on subjects such community engagement, working with schools, and film-making.

- **Famelab**
A talent competition to find the UK's best new talent in science communication, organised by the Cheltenham Science Festival in partnership with NESTA. This competition appears to run biannually, and is a kind of talent show for young scientists, who take part in regional heats. The last competition involved an international element,

with the search for the best talent in Europe.

- **MP-scientist pairing Scheme, The Royal Society**

Scientists are paired with UK MPs. The scheme is made up of three activities: a briefing by the Royal Society, a week in Westminster, and reciprocal visits to the constituency office and laboratory. There were 24 scientists participating in 2007.

The predominant model for early involvement in public engagement in the UK seems to be the school-based project. The Beacons project appears to be the only support scheme which deals with general communications as well as school pupils. New schemes such as the Beacons scheme and the Researcher in residence place emphasis on training, careful planning team-working (for example, with partner schools) and support. However, in most schemes, professional development appears to come from doing, with a small amount of initial guidance. One assumes that participants submit some kind of report or personal evaluation at the end of these schemes (for example, the evaluation forms completed by researchers in residence for the Royal Society¹⁵) but there is no real focus on professional development.

If anything, the communication skills themselves do not seem to be articulated. There is an assumption in these schemes that scientists will get better at communicating, and they will learn from the experience; but whatever they do learn appears fairly personal. It is possible that learning is shared informally, though the training sessions and occasional conferences in the field.

Textbooks

There are many textbooks now available which attempt to provide a guide to communications skills for scientists and engineers. While some of these are aimed at masters-level students of science communication, there are plenty of practical guidebooks. Buchhi's *Handbook of Public Communication of Science and Technology* (2008) is an example of a fairly heavyweight textbook, providing readings on science in popular culture, lay perceptions of risk, and recent health controversies, as well as accounts of science communication. Gregory and Miller's *Science in Public: Communication, culture and credibility* (1998) covers similar ground, analysing the state of the 'public understanding of science' movement.

On the more popular side, there are many guidebooks published by the research councils and by experienced practitioners. These typically have something of a 'deficit model' of scientists' abilities to communicate. Venables' *Communication skills for Scientists and Engineers* (2002, published by the Institute of Chemical Engineering) is a typical title, offering plenty of practical advice on how to present research to non-specialist audiences. Wilson (1998) and Woodford (1999) present similar approaches. The Royal Society of Chemistry's *Getting the Message Across* (1999) contains similar advice to the other handbooks, packed in a small brightly coloured ring-bound book.

Development from other membership organisations

As noted earlier, science communication is fairly fragmented as a career. There are some membership organisations providing information, support and a professional focus. The British Association [now the British Science Association] seems the nearest to a general umbrella organisation for career science communicators, running an annual Science Communication Conference attended by around 350 people.

STEMPRA represents people working in public relations/press officer roles in science, technology, engineering and medicine. The association holds talks, runs training days, produces a newsletter and has a discussion list for people working in science communication.

The Association of British Science Writers¹⁶ also maintains a network and runs conferences.

Other networks appear to ebb and flow, with a Google search and Psi-Com search revealing various networks, some of which seem to have fallen by the wayside. There is also a considerable amount of support provided by the programmes and networks of the research councils and learned societies, although once again this is likely to be used by ‘career’ science communicators rather than those doing some science communication as an adjunct to their main job.

Approaches outside the UK

This review has focused on the UK situation, but training in most other parts of Europe and the USA appears to take a similar path to the UK. The one approach that stands out is Questacon/Australian National University’s Science Circus¹⁷ (of which Bronwyn Terrill is a graduate). This differs sharply from most other courses on science communication in its uniquely practical orientation, with students planning and delivering Science Circus activities across Australia for 18-20 weeks.

3.3. Some conclusions from reviewing current UK professional development

Are there any lessons for the Sanger Institute in this list of UK activity? There appears to be a fair amount of funding for projects in schools. The Beacons project and (possibly) Famelab stand out as those most likely to develop new talent in public engagement. The emphasis on continuing professional development in the Beacons project appears to continue beyond initial training.

The evidence, then, from current provision in the UK is that while there are plenty of schemes where scientists can try out their engagement skills with the public, there is a limited amount of support and development beyond a brief period or initial training and orientation. Furthermore, there is very little evidence that course developers have considered professional development as an issue.

The prevailing development models are either a) to provide brief training and then encourage scientists to interact with the public or b) to encourage scientists to develop and carry out a project, usually with a partner. While it is true that running a project involves a huge learning curve, in terms of planning, managing and evaluating, the core activity of communicating does not appear to get much attention.

Does this lack of emphasis on core skills matter, especially if scientists are going to be testing out their skills with real projects, and will therefore learn from their experience as they go?

Individual projects do offer a huge learning experience, often with a steep learning curve as the scientist attempts to put their communication vision into practice. However, scientists need time to try approaches and practise, before finding a style of communication that suits them.

Another objection to blanket training is that scientists' development needs are extremely individual – one scientist may need help in classroom management, another may need support in developing activities or explanations. Arguably, project-based development means that scientists will learn how to manage their audiences in a real situation, learning as they go. Some schemes also assume that partners such as science teachers will provide coaching and feedback.

The opposing argument sees the lack of further training as a weakness. A bad experience with a project will deter the scientist from taking on future projects. Communication settings are also very individual – what works with one group in one setting may not transfer to an audience with very different needs.

Furthermore, project partners and mentors may not actually be in a position to offer critique – they may simply be happy that the scientist gave up their time.

Perhaps the greatest difficulty with lone practice is that while scientists may find a style of engagement that they are comfortable with, they may not develop their practice much beyond this.

Studies of beginning teachers (see Loughran et al, 2007, for a review) show that while teachers develop an initial teaching style through their continued exposure to real classrooms, the approach that they choose is often not what their initial teacher education intended, and indeed may be less effective. The effective approach is not necessarily the one that feels most comfortable to the beginner: on the contrary, it may require a lot of work and practice before the novice teacher can deliver it in the classroom.

Loughran et al (2007) quote examples from science teacher education, showing that while lecturers were able to create powerful learning experiences for student teachers, students did not necessarily bring these into their own practice; instead, they fell back on safer practices or indeed practices that they themselves had formerly rejected.

Watter and Diezman (2007) argue for the importance of learning cycles, involving practice, feedback from the situation, reflection and evaluation. Practice and reflection are thought to be the critical elements of the cycle.

While Watter and Diezman (2007) view reflective practice as the gold standard in improving teacher performance, they also emphasise the importance of good models for new teachers to observe, and they assume that the beginning teacher is already familiar with the curriculum, the assessment regime, and a range of different instructional strategies.

In contrast to this deliberate development, much early scientist public engagement takes place in something of a vacuum. Newer funded schemes, like Sanger Institute training, do recommend reflective practice as part of their core approach - in other words, mindful, self-conscious observation and critique of one's own practice. However, given that initial training is very brief, and follow-up is limited, it is not clear how much scientists actually do this.

4. Interlude: Case studies from other fields

While science communication is unregulated, with no clear training route (and arguably is unlikely to be systematised in the near future), there are plenty of similar activities which are carefully constructed and regulated. In this interlude, three cases are considered: teaching (specifically secondary science teaching), medicine and for a complete contrast, football refereeing. All three of these examples involve far more training and regulation than exists within science communication. However, a detailed look at their practices generates plenty of insights into how training or development might be constructed. The context of science communication makes it unlikely that these practices could be adopted wholesale, but the approaches are well worth understanding.

Of the three, teaching stands out as the example which is closest to the task of science communication as practised at the Sanger Institute. Teaching research and teaching journals contain a wealth of information on classroom engagement, good practice, and experiments. Pedagogical work, in particular, feels like the missing link between general understanding of communication, and advice on presentation skills.

Case Study 1: Becoming a science teacher

The main postgraduate route for becoming a qualified secondary school teacher is the Postgraduate Certificate in Education. To gain a professional qualification recognised by the TDA (Training and Development Agency for Schools), student teachers need to complete the PGCE and meet all the requirements of the qualified teacher scheme, including successfully passing a set of basic skills tests.

Teacher training typically covers school-based learning and practical teaching, subject and curriculum studies, and professional practice. Following an initial period of induction, trainee teachers spend most of their time in schools. The Institute of Education's PGCE, for example, involves 4 days per week in school in the first term, and 5 days in the second term, interspersed with study period.

During practical teaching experience, students typically keep extensive logs of their lessons, their lesson plans, their observations of lessons and reflections. Some of their lessons are observed and assessed, and student teachers will typically meet with their mentors to discuss progress and set development targets.

Looking at the detailed curriculum guide for one secondary science PGCE course from the Institute of Education¹⁸, we can see the inclusion of various different elements within initial training:

- School induction (an introduction to the school environment)
- Student teacher observation of lessons (initially structured with the help of observation tasks) and shadowing of teachers/pupils
- Formal instruction, especially at the beginning of the year

- Hands-on practice (staged from teaching small groups to larger groups, and teaching part lessons to whole lessons; increasing in level over the PGCE year)
- Self evaluation and reflection, recorded in a log
- Feedback and assessment (in early experience and later experience, staged regularly)
- Regular discussion and mentoring
- Group tutorials
- Study tasks /formal assignments, including special projects
- Reviews and personal development plans

Student teachers also study and learn pedagogical skills, which they apply during their teaching practice. Pedagogical skills include the following areas:

General skills

- Preparing topic plans for teaching a subject over a period of time
- Preparing individual lesson plans, with associated outcomes
- Evaluating the lesson afterwards
- Using a reflective process, the reflective circle, to plan out, practise and assess their teaching (reading, teaching, evaluating, each accompanied by critical reflection)
- Classroom skills

Subject-specific skills for science

- Taught sessions on physics, chemistry and biology, to help new teachers map the field
- Subject scaffolding on specific topics, to build teachers' broad knowledge of science
- Diagnosing one's own understanding of science and developing it further
- Understanding the role of practical work
- Management and organisation of science lessons
- Sex and health education within science education, including legal aspects
- How science works

Assessment

Progress and competence are assessed via a wide variety of tasks, including:

- Completing an ongoing profile of personal progress throughout the year
- School-based science tasks
- Passing assessed modules on science education
- Developing a professional learning portfolio
- Keeping a practical teaching file
- Passing regular audits in science knowledge
- Passing basic skills tests and ICT tests

Post-qualification, teachers' performance is regularly assessed against professional standards¹⁹. These standards are divided into three areas, knowledge and understanding, practical skills, and personal attributes (KSAs again). The specific

standards expected of teachers at different stages (e.g. Excellent teachers) are very clearly laid out and defined in positive behavioural terms.²⁰

So, for example, one professional attribute is having a general awareness of professional duties and workplace policies, and helping to implement these. Levels of performance are specified as follows:

1. **Core teachers** (all teachers) should have up-to-date knowledge and help contribute
2. **Post threshold teachers** should contribute significantly to implementing policies
3. **Excellent teachers** should be willing to take a leading role on these issues
4. **Advanced skills** teachers should be able to take a leading and strategic role

Learning from science teaching

There are of course many ways in which science teaching is not relevant to public engagement, especially in the Sanger Institute context. Teachers follow a tightly defined curriculum, and are judged, in part, by their students' success in their subject. Teaching is highly regulated, both during and after initial training, and teachers are used to observation and external assessments of their performance.

Teaching is also chiefly concerning with helping pupils master a body of knowledge, rather than, say, debating ethical issues.

In contrast, public engagement deals with general audiences as well as school pupils, and potentially draws on a much broader scientific context.

However, there are many ways in which science teaching is an extremely helpful model for someone looking at designing processes in science communication.

First, initial teacher training uses an explicit process which is intended to furnish the student with the knowledge and skills to perform as a competent, independent professional. Teacher training achieves this in part by providing the student with a set of structured, progressive experiences that will help the student teacher to craft their own practice.

Second, teaching has a body of knowledge on effective teaching and learning, which is unlikely to be familiar to science students, but which is used implicitly in much science communication. For example, the prevailing paradigm in designing museum exhibits and learning experiences is constructivism, where students are thought to learn best through active, interaction. Current thinking in pedagogy is that 'purist' constructivist approaches (i.e. always teach through experience, never lecture) are a naive interpretation of constructivism (Bransford et al, 2000). While adults and young people always come to new information with pre-existing understanding, they may learn very effectively from straightforward instruction.

Finally, teaching can also contribute many practical ideas for explaining or teaching complex science. For example, interactive lecture demonstrations are useful for helping students overcome persistent misconceptions. Lectures start with an

introduction to the problem, and to the practical exercise that is about to be demonstrated. Students are asked to discuss what they think will happen and why. The demonstration is quite different to students' expectations, and the post-demonstration discussion can begin to look at what is happening and build new understanding of the theory.

Case study 2: Postgraduate medical education

Postgraduate medical education has been reorganised at frequent intervals in the last 15 years, most recently in response to the 2007 crisis following an attempt to introduce a standardised electronic applications system for doctors applying to train as specialists.

Immediately after graduating from medical school, doctors embark on a two-year foundation programme, that allows them to experience a range of different specialties. Trainees typically experience six 3-4 month rotations over the two years, which allow them to sample a whole range of specialties. The curriculum for the foundation years stage is carefully constructed and approved,^{21 22} with trainees required to acquire specific skills and levels of expertise each year.

Following this stage, doctors are required to specialise. Those who wish to practise as GPs undertake specific training; those who wish to specialise in hospital medicine embark on extended training, proceeding through seven different stem points (specialist training grades).

The shape of postgraduate medical education differs greatly between specialist medicine and GP training. Specialist training is seen as more ad hoc, closer in spirit to the traditional master/apprentice model. GP training is more formalised and regulated. GP trainers apply to become trainers, receive training in how to teach, and are paid. Training time is protected. In contrast, most trainers in hospital medicine are not trained. A Scottish study quoted in the 2008 PMET Review found that only 6% of consultants had a training qualification, and 48% had not attended a workshop on education. Structured training has come late to hospital medicine: 2007 was the first year in which all 57 medical specialities had approved curricula and assessment methods.²³

Medicine has largely adopted the competency approach, with competencies for each stage in Foundation training carefully laid out.²⁴ This is not universally welcomed: Fish and Coles (2005), in a critical review of the curriculum proposals contained in the 2003 'Modernising Medical Careers' review²⁵, comment that 'competency' is easily (and unhelpfully) confused with 'competence' within the framework.

During the Foundation stage, trainees are required to record their achievement in a portfolio; assessment is done by supervisors and peers, with reference to the standards laid out for each stage, and much assessment is 'work-based assessment' by the educational supervisor.

Work-based assessments can take various forms:

- Direct observation of procedural learning (for example, the assessor watches the trainee perform a task)
- Multi-source feedback (feedback from peers and other staff)
- Mini clinical evaluation exercises
- Case-based discussions, reviewing cases with a senior clinician

Trainees are responsible for arranging their own observations and assessments over the year, and recording these in a portfolio. The intention is that the portfolio should show evidence of improving skills over time. Medical education has also embraced the concept of reflective practice, and so the portfolio should also include reflective pieces, to support this goal.²⁶

When initially looking at the literature on skills development, medical education seemed like a relevant field, in that it involves teaching complex skills to adults who are already knowledgeable (i.e. like Sanger Institute scientists). However, it is perhaps the evolution of medical education, and the continuing debates about how medical knowledge should be taught and assessed, that are the most interesting elements. Fish and Cole (2005) felt strongly that the new framework for education was mechanistic and impoverished, lacking an awareness of skilled, intelligent practice. In their eyes, medical training easily becomes a production line. In their eyes, the curriculum is cosy, when it should involve uncertainty and challenge. Calman (2007) also highlights the need for medical pedagogy, as a way of raising standards during training. He quotes from a 19th century medic on the need for structure and professional practice during training:

‘A few books and some oratorical gifts no longer suffice to make a medical teacher.’

Two elements in medical training stand out. The first is the idea of **rotation**, where students experience different settings and subject areas in turn, with the expectation that students will amass a general education and at the same time decide where their interests and talents lie. In contrast, science communication training, where it exists, seems focused on a few skills rather than producing rounded communicators.

The second learning point is the **list of competencies** for each foundation year (ref) which trainees tick off as they go. There is no implied hierarchy among the items, although the items for the second year build and extend those gained in the first year. The list provides a quick check of all the things that a beginning doctor ought to be able to do at each stage.²⁷

Case study 3: Becoming a Football Association referee

The process of becoming a certified Football Association referee is an interesting one. Apart from a small number of professionals, most referees are amateurs who do it for love of the game and the desire to contribute: they have no particular desire to go further than refereeing youth teams and other amateur team, and they referee in their spare time.

Unlike science communication, however, refereeing is overseen by the Football Association, and is subject to a great deal of structure (i.e. adhering to complex FA rules, complying with FA policies and guidelines). Like science communication, refereeing is a dynamic process involving subject knowledge and the application of good people skills. Training and post-qualification development is structured very carefully.

Amateur referees start by registering with their local county and taking a refereeing course. They need to have police checks before they can embark on a course.

Training involves lecturing, discussion, viewing videos, completing assignments, and attending a child protection session

After the initial course, trainee referees have to pass an exam testing them on football rules. They are then instructed to go and referee 6 matches as soon as they can. During the first of these they will be accompanied by an experienced referee, who provides advice and feedback at the end of the match. They may also be anonymously assessed by an experienced referee for one of these matches. When the trainee has successfully refereed six matches, they are certified as a qualified FA referee, and their initial training costs are refunded. They then go on to referee more matches, with 1 in every 6 being observed. Furthermore, all referees are awarded a score by the managers of both teams at the end of every match, and these scores are sent to the local F.A. New referees have access to a mentor, for telephone advice on handling difficult or uncertain situations.

The system, then, involves formal instruction and assessment followed by periods of practice. The system of frequent observation interspersed with practice means that referees get feedback fairly quickly on their performance, and gradually grow in confidence. From the FA's point of view, the system seems to encourage good compliance to refereeing guidelines (the frequent feedback from managers and the formal assessments mean that they can't drift too far from the original guidelines), while allowing new referees to learn to cope with matches by themselves. Further development is available through training and the gradual move to refereeing higher-level games.

Referees are also supported by a membership organisation, FAMOA, which sends out a regular magazine and provides training and learning opportunities. New referees keep an individual portfolio, which includes training certification and awards. Referees who undergo training and referee further matches receive rewards such as free kit.

Refereeing is clearly a very different activity, which takes place in a highly structured setting. However, the mix of training, examination, practice and assessment means that new referees pick up skills and develop good habits, in a supportive atmosphere.

What can science communication training learn from amateur referee training? The emphasis on **frequent practice interspersed with observed and assessed practice** seems a good way of giving new trainees scope to experiment, while ensuring that they get prompt, timely feedback.

The **portfolio** is a useful way of keeping all information in one place, although in the case of science communication, it's not clear whether trainees would have enough commitment or identification with public engagement to really follow this through.

The final element of referee training is its **emphasis on rewards**. When new referees have completed six matches, they are refunded their course fees. They also get kit and badges. Although most referees work for love of the game, modest rewards are built into the structure right from the beginning. Are there ways in which new science communicators can receive some kind of modest reward? It's not clear whether this approach could transfer, but it's a feature of refereeing that helps create a positive climate for encouraging refereeing.

5. Conclusions and recommendations from the literature review

From the review of literature and training development, it would appear that there is no pre-existing model for professional development in science communication. There is plenty of initial training and support for scientists who want to become involved in science communication, and there are postgraduate degrees for those with an interest in specialising in science communication or science and society. There is little in the middle. The developing Beacons for Engagement projects appear to have the greatest potential to help develop skills in talking to the general public.

There is extensive support for helping scientists deliver small-scale science communication projects in schools, and there are some ad hoc projects which aim to give experienced scientists extended experience of working with the media. However, the assumption behind most existing initial training is that the scientist can be briefly trained and then dispatched to the field.

While this model is similar to what happens within, say, management, there are many professions which require much more in the way of supervision, assessment, feedback and the achievement of certain skills.

Although there is a strong emphasis on the term ‘engagement’ within science communication, there appears to be very little training aimed at developing face-to-face engagement skills. The emphasis is on presentation skills and project management skills.

Evidence suggests that the content of current Sanger Institute scientist training is appropriate, and the current model of informal assessment, training, low-key observation and feedback offers reasonable support to scientists.

However, there are some practical difficulties in considering professional development of science communication skills at the Sanger Institute. First, there is a possibility that the context in which skills are used is quite restricted – so, a scientist who usually talks about one aspect of Sanger Institute research may become quite good at delivering his or her piece, but may struggle if switched to something different.

Second, we do not know a great deal about the development of mid-level science communication skills, although we can extrapolate from the skills of experienced communicators. It would be very valuable to look at the experiences of mid-range science communicators, in order to build a framework in which new communicators can build their skills up quickly and effectively. Some useful evidence may already have been gathered by the Wellcome Trust or other research councils.

Finally, the context of practice is challenging, in that the Public Engagement team are recruiting volunteers who want to become involved in science communication as an ancillary activity, and are unlikely to become professional science communicators.

Their voluntary status also makes it less likely that they will be seeking formal accreditation – indeed, they may not consider ‘performance’ to be part of their involvement.

From the review of development in other fields, there are a number of ideas that it seems well worth applying to science communication. Teaching in general (and science teaching in particular) is a rich source of ideas and frameworks. The recommendations for the next phase of developing a professional framework are as follows:

Fundamentals

- Consider the core skills, qualities and values which the Sanger Institute wishes to foster in scientists who take part in public engagement work
- Develop a detailed vision of the novice science communicator, the improving and the skilled science communicator at the Sanger Institute, and define each of these (with the help of input from mid-level communicators)
- Develop a checklist of core competencies for science communication, and group these according to knowledge, skills and attributes; try to identify what would constitute adequate, good or outstanding performance in the area
- Aim to develop skills in presenting, teaching, and engagement
- Draw on the pedagogical knowledge built up in analogous fields, such as science teaching
- Encourage new communicators to use learning cycles, i.e. to learn, try and apply skills taught in training
- Focus on encouraging communication practice soon after training, ensuring a mix of lone practice with observed practice
- Ensure that new practitioners receive support, observation and feedback through the early days
- Assess performance during training sessions and during observed work, before putting scientists in more challenging situations
- Explore what is possible in terms of formal development, with scientists and their supervisors

Development beyond initial training

- Encourage scientists to try new skills or work with new audiences, once they are comfortable with what they are doing
- Offer further development opportunities, either through further short bursts of training (for example, developing interactive skills; thinking about the A level curriculum) or via projects and competitions
- Consider what is possible within the constraints and brainstorm alternative approaches. For example, would the Sanger Institute consider team-based approaches? Is there scope for providing some kinds of reward?

- Consider a light form of professional development, where scientists keep a file of talks given, notes and reflections on practice, and have informal reviews and individual development plans with someone from the public engagement teams

6. The preliminary framework

6.1 Approach

The preliminary framework, listed on the following pages, is based on the structure of current teaching standards. Attributes are grouped into three broad areas: professional knowledge, skills (in presenting, teaching and engaging), and personal/professional attributes that are the hallmark of good practice.

Each attribute can then be broken down into levels where necessary. At this preliminary stage, we have outlined three stages, or levels of performance: performance expected from any Sanger Institute science communicator, including novices; improving performance, and skilled performance. Some of these levels are defined, others need further work and further discussion.

Taken together, this list of attributes needs to paint a complete picture of skilled practice in science communication as it applies to the Sanger Institute context.

The final list of attributes, along with a second list of core activities capable of being done by novice, improving and skilled communicators, should provide a basis for self-assessment, charting progress, and guiding development conversations.

6.2 Sketch of the framework

A preliminary framework		
All scientists communicating with the public should:	Improving science communicators should also:	Excellent science communicators should also:
Professional and personal attributes		
1. Demonstrate positive values that they expect from their audiences		
2. Have high expectations of the audience		
3. Respect difference in understanding and differences in attitudes		
4. Relate well to different groups e.g. students, teachers, general public, other scientists		
5. Understand the scientific method and be committed to explaining and elucidating science	Be aware of audience difficulties in understanding the scientific method, and be able to talk about these	Be aware of different paradigms, and understand how they relate to the scientific method
6. Be interested in moral/ethical dimensions of scientific practice		

Professional and personal attributes		
All scientists communicating with the public should:	Improving science communicators should also:	Excellent science communicators should also:
7. Be open to new ways of working		
8. Reflect on their practice, and try to learn from their experience		
9. Be open to constructive feedback		
10. Operate in a professional manner at all time		
11. Be aware of any legal restrictions or consideration on the content they are discussing		
Knowledge and understanding		
12. Have a secure knowledge and understanding of research conducted at the Sanger Institute		
13. Have a good knowledge and understanding of research conducted more broadly		
14. Be aware, where relevant, of main features of the curriculum for student/pupil audiences		
15. Understand the Science in society/public engagement standpoint of the Wellcome Trust		
16. Understand basic theory of how adults and teenagers learn about		

science		
17. Be aware of requirements or sensitivities regarding discussion of personal/health issues with young people		
18. Be aware of relevant controversy/ethical issues within the field and can take these into account when presenting material		
Science communication skills		
All scientists communicating with the public should be able to:	Improving science communicators should also:	Excellent science communicators should also:
19. Plan a talk or activity, taking audience knowledge and needs into account		
20. Present clearly and engagingly to small groups, drawing on a range of approaches	Facilitate discussion	
21. Elicit and answer audience questions	Facilitate general discussion	Use a range of approaches, including discussion, debate and deliberative approaches
22. Build on the audience's prior knowledge and conceptions, making links between their knowledge and the science area being discussed		
23. Adapt material and delivery in advance to suit the knowledge and needs of different audiences		

All scientists communicating with the public should:	Improving science communicators should also:	Excellent science communicators should also:
24. Provide examples, activities and metaphors that the audience can relate to		
25. Flexible in the approach with a group, changing tasks to meet the situation		
26. Make use of feedback	Collect and respond to feedback	Use feedback to improve own performance
27. Manage groups effectively, using appropriate techniques to stimulate discussion or deal with challenging behaviour		
28. Work collaboratively with the public engagement team, to share ideas and develop good methods		

7. Refining the framework

7.1 Testing assumptions about skills development

The provisional framework document was presented to the Sanger Institute in December 2008. Some of the assumptions behind the framework were tested during science communication workshops that took place in early 2009. By seeing participants' response to the training, and attempting to examine performance using the framework, we were able to understand some of the underlying issues and necessary refinements more clearly.

The earlier document suggested that scientists involved in science communication at the Sanger Institute do this work as a minor adjunct to their main role. As such, it is unlikely that they will develop science communication skills to the same level as someone who specialises in this kind of work full-time.

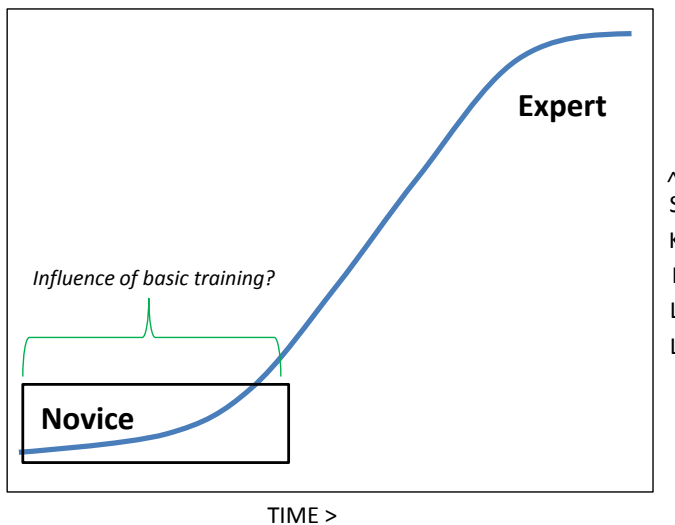
This suggestion appears to be fairly accurate. For the most part, scientists involved in science communication at the Sanger Institute are likely to start by guiding visitors on a site tour and giving talks and demonstrations as part of that site tour. Scientists who seem confident with handling more complicated interactions may be asked if they would like to take part in further engagement activities such as science cafe talks and ethical discussions. The Public Engagement team take care not to overburden scientists, whose participation in public engagement activity is entirely voluntary.

7.2 Revisiting the journey from novice to expert

The journey from novice to expert in a given field was conceptualised in the diagram below, where the X axis shows time and the Y axis shows level of skill. Over time, general expertise rises to its maximum. In the example here, expertise eventually reaches a high, asymptotic level after an extended period of time.

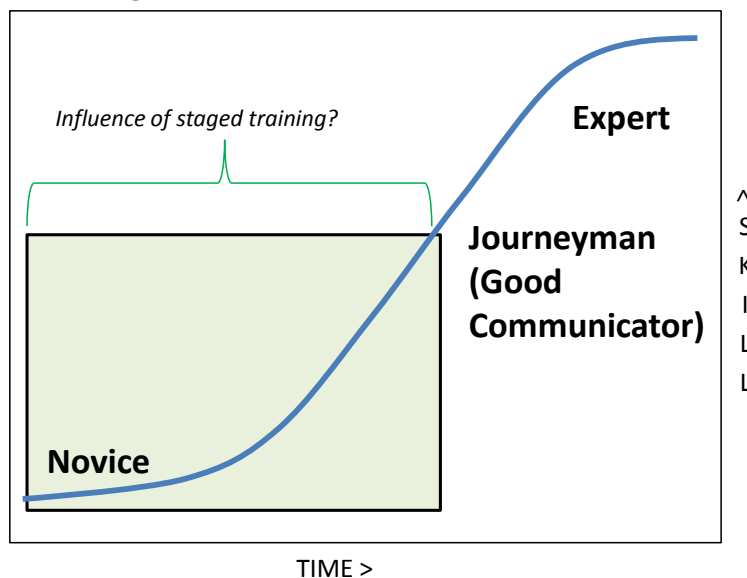
In the earlier framework document, I proposed that the actual journey in expertise for someone involved as a science communication volunteer at the Sanger Institute was likely to be more limited compared with the degree of development possible for someone who took this up as a professional specialism. The original graph (below) showed a very small zone of influence from the basic training:

The journey to expertise



In fact, although the development possibilities at the Sanger Institute may be more limited than for someone involved in science communication full-time, they are probably somewhat broader than this initial diagram showed. More like this in fact:

The journey to expertise – Sanger Institute zone of influence



Here, the shaded area shows the zone of influence from involving scientists in public engagement work. Although it might be difficult to give someone the amount of practice and training necessary to become an expert in the field, there is enough scope

(especially given planned future developments) for someone to make the journey from novice to seasoned communicator.

7.3 Changes made to the framework

In testing and discussion, we refined our view of stages in skills development, and we amended some of the attributes used to define performance. We also thought through the implications of this stage view for the kinds of training and practice which the Public Engagement team should offer to scientists. I have highlighted *practice* here, because training needs to be tested out in practice and personal experimentation. Without opportunities to practise these skills, scientists' development in this area is likely to be limited.

The revised framework uses three stages of development for science communicators, like the original framework. However, the outline levels of expertise used in the initial framework document are replaced with three different types of interaction with the audience. These three stages are:

- Presenter
- Teacher/Populariser
- Debater

I would argue that these three stages reasonably represent the pattern of skills development in science communication at the Sanger Institute. Novice science communicators start off by learning how to present their science effectively to non-expert audiences. They then learn how to interact with different audiences, and how to build their audience's knowledge. I have characterised debate as the most complex of the stages, as it involves managing the audience sensitively as well as having good broad knowledge of the science and the ethical debates around it.

At the intermediate level, there is scope for scientists to develop as communicators in various different ways. Greater involvement as a presenter/teacher is one way in which scientists build their expertise. Scientists with some experience might also want to develop their experience further by talking to adult groups such as the WI or Cafe Scientifique-type audiences. I would argue that this type of involvement is more complex than presenting as part of a tour, and less difficult than leading a debate. However, it needs knowledge, confidence and the ability to interact effectively with audiences. The intermediate level might not be so much about increasing expertise (climbing up the curve) as broadening experience.

Science communication training and development should be designed to help scientists to acquire and practise these skills. I would envisage a mixture of formal workshop training, augmented by ongoing mentoring and support (to help the scientist develop his or her skills) and informal 'journal club' sessions aimed at helping scientists think about specific subjects in science communication.

If scientists are to genuinely learn new science communication skills, then they also need to have the opportunities to practise these skills very soon after taking part in

training. Training and development, therefore, needs to match the kinds of real public engagement activities that scientists are involved in.

The three stages are outlined below. Longer definitions, along with an indication of the training and experience required at each level, are listed on the next page.

Stage	Approximate timing
<p>1 Presenter</p> <p>The presenter is a beginning science communicator who is learning how to present their work clearly and confidently to a range of audiences.</p>	<p>After Level 1 introductory training</p>
<p>2 Teacher/populariser</p> <p>The teacher (or tutor/demonstrator) is experienced in talking about their own work, and is learning how to interact effectively with audiences from different backgrounds, building on their knowledge and relating it to science done at the Sanger Institute.</p> <p>The populariser may be less comfortable with teaching, and more comfortable with talking to a lay audience about their work.</p>	<p>After Level 2 training/experience</p>
<p>3 Debater</p> <p>The debater is comfortable with talking about sensitive, difficult or ethical subjects with different audiences, and is able to manage participation from audience members with differing viewpoints/ levels of knowledge</p>	<p>After level 3 training/experience</p>

The amount of time or experience that is required to go from one level to the next is not clear. The first few presentations will usually represent a steep learning curve for the participant. I would say that at least 10 talks were required to move from novice to a more experienced level, although some scientists (for example, those who were already comfortable with public speaking) might progress faster.

The chart on the following page outlines the kind of activities that scientists at each level might take part in, together with a broad outline of the type of training required to develop their skills.

Skills and experience	Training and development content
1 Presenter	
<p>Giving talks as part of the tour Giving standalone talks about one's own science</p> <p><i>Gaining practice and self-confidence</i></p>	<p>Level 1 introductory training</p> <ul style="list-style-type: none"> - Audiences - The nature of engagement - Practice in presenting - Understanding the curriculum <p>Continuing development</p> <ul style="list-style-type: none"> - Mentoring & feedback
2 Teacher/populariser	
<p><i>Teacher:</i> Giving standalone talks to A level students Giving longer or more complex talks Relating one's science to the curriculum Setting one's science in a broader context</p> <p><i>Populariser:</i> Giving talks to other non-expert groups Presenting at Cafe Scientifique-style events Talking at the Cambridge Science festival Bringing complex science to life Writing about science</p> <p><i>Experimenting with different approaches and different media</i></p> <p><i>Constructing longer sessions</i></p> <p><i>Gaining experience in talking or writing</i></p>	<p>Level 2 training/experience (Modular)</p> <ul style="list-style-type: none"> - Knowledge mapping (with guidance from an education specialist) - Storytelling skills - Other specific skills e.g. filming, writing for the internet, devising exhibits
3 Debater	
<p>Talking about ethical aspects of one's work and that of the Sanger Institute Talking with groups that have diverse concerns</p> <p><i>Gaining experience in tackling difficult subjects</i></p> <p><i>Leading discussion</i></p>	<p>Level 3 training/experience</p> <ul style="list-style-type: none"> - Scicomm journal club, mapping knowledge of ethical debates and media coverage - Workshop on ethics - Training in deliberative methods

The revised framework (based on the attributes listed on the following pages) is loosely based on the structure of current teaching standards. Attributes are grouped into three broad areas: professional knowledge, skills (in presenting, teaching and engaging), and personal/professional attributes that are the hallmark of good practice.

We made some changes to the attributes used. Most changes were made to the cluster of attributes representing professional and personal qualities. We gave greater emphasis to interest in communicating, openness to learning, and respect for the audience. Professional knowledge attributes are virtually unchanged. Skills attributes also changed little, but we placed greater emphasis on learning to interact with the live audience.

In our current framework, each attribute is given a general definition, and then broken down into levels of performance, corresponding to the specific quality of performance expected of a presenter, a teacher/populariser, and a debater. Some attributes are constant across all levels of performance (e.g. a positive and professional attitude is required for all types of science communicator); most will change markedly for a debater as opposed to a presenter or populariser. For example, one attribute under the heading of 'Knowledge and Understanding' is 'aware of audience understanding.' We tried to define exactly what type of audience understanding was necessary at each level. So, presenters needed to be aware of their audience's general level of understanding, and relate their material to that. Teachers and popularisers needed a broad understanding of prevailing science curricula, and debaters needed to be aware of their audience's response to ethical and moral dimensions of the science.

Presenters, teachers and debaters also need slightly different skills, which we would argue build on one another. So, one of the 'Skills' attributes is 'managing groups effectively.' This means slightly different things at each level. Presenters need to be able to manage groups effectively, by issuing clear instructions, and engaging with participants; teachers and popularisers need to manage audiences at a deeper level, by stimulating discussion and dealing with challenging behaviour; debaters need to be able to do all of these things, and be able to encourage the audience to express a range of views .

One of the greatest development challenges we face is to successfully support scientists in the move from general presenting to a more interactive and engaged style. This project has begun to define what skills are involved, and how these may be fostered through a mixture of training and hands-on practice. Over the next year, we plan to test the framework with different groups. The levels of performance will be refined during the coming year; and some important attributes (e.g. respect their audience; able to think on one's feet; engage in reflective practice) will undergo additional exploration and clarification to help observers to consistently characterise different skill levels. We will present and publish the completed working framework for discussion/review by the Public Engagement community in 2010/2011.

The guiding intention is to develop something that is genuinely helpful both to the community of scientists working at the Sanger Institute, and the external audiences we serve.

7.4 Revised attributes

Professional and personal attributes

1. Show an interest in communicating science to non-expert audiences
2. Positive and professional attitude
3. Respect their audience
4. Relate well to different groups
5. Understand the scientific method and are committed to explaining and elucidating science
6. Open to learning about public engagement
7. Engage in reflective practice
8. Open to receiving feedback
9. Are aware of any legal restrictions or sensitivities

Attributes related to knowledge and understanding

10. Have a secure knowledge and understanding of research conducted at the Sanger Institute
11. Aware of audience understanding
12. Understand the Wellcome Trust's commitment to public engagement
13. Understand how adults and teenagers learn about science
14. Aware of requirements or sensitivities regarding discussion of personal/health issues
15. Aware of relevant controversy/ethical issues

Science communication skills

16. Plan a talk or activity, taking audience knowledge and needs into account
17. Present clearly and engagingly to groups
18. Interact with the audience
19. Relate their science to the audiences' real-life interests, knowledge and concerns
20. Adapt material and delivery in advance to suit the knowledge and needs of different audiences
21. Provide examples, activities and metaphors that the audience can relate to
22. Able to think on one's feet
23. Make use of feedback
24. Manage groups effectively
25. Work collaboratively with the Public Engagement team, to share ideas and develop good methods

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Footnotes

- ¹ <http://www.biocareers.org.uk/scicom2.htm> Dated approximately 2007.
- ² UCAS course search <http://search.ucas.co.uk/cgi-bin/hsrun/search/search/StateId/DQn6robtZUCKTp5cbuXgYVNKTGR23-UU53/HAHTpage/search.HsKeywordSuggestion.whereNext?query=3545&word=SCIENCE+COMMUNICATIONS&single=N>
- ³ British Council list of M.Sc. courses <http://www.britishcouncil.org/talkingscience-education-and-development-qualifications.htm>
- ⁴ British Association list of degree courses in science communication. http://www.the-ba.net/the-ba/ScienceinSociety/Courses_and_Training/Science_Communication_Courses.htm
- ⁵ Intute database listing of science communication courses http://www.intute.ac.uk/healthandlifesciences/cgi-bin/browse_pscicom.pl?id=45
- ⁶ M.Sc. in Science Communication, University of the West of England . <http://courses.uwe.ac.uk/p90012/2009>
- ⁷ M.Sc. in Communicating Science, University of Glamorgan. <http://www.glam.ac.uk/coursedetails/685/585>
- ⁸ Wolfendale report <http://collections.europarchive.org/tna/20060215164354/http://www.dti.gov.uk/ost/ostbusiness/puset/report.htm>
- ⁹ 'Survey of factors affecting science communication by scientists and engineers, Royal Society, RCUK and Wellcome Trust, June 2006, available at <http://www.royalsoc.ac.uk/page.asp?id=3180>.
- ¹⁰ <http://www.britishcouncil.org/talkingscience-education-and-development-opportunities.htm>
- ¹¹ <http://www.stemteamcambridgeshire.org.uk/index.html>
- ¹² <http://www.stemnet.org.uk/>
- ¹³ <http://www.rcuk.ac.uk/sis/beacons.htm>
- ¹⁴ <http://www.publicengagement.ac.uk/nccpe/default.htm>
- ¹⁵ Evaluation forms for the Researcher in Residence scheme. <http://royalsociety.org/page.asp?tip=1&id=1952>
- ¹⁶ Association of British Science Writers <http://www.absw.org.uk/>
- ¹⁷ Questacon Science Circus <http://sciencecircus.questacon.edu.au/>
- ¹⁸ Institute of Education Secondary PGCE Course Handbook, 2008/9.
- ¹⁹ The standards for newly qualified teachers http://www.tda.gov.uk/upload/resources/pdf/s/supporting_the_induction_process_nqt.pdf

²⁰ The Teaching Standards framework in detail.

http://www.tda.gov.uk/upload/resources/pdf/s/standards_framework.pdf

²¹ Links to descriptions of the Foundation Programme. http://www.gmc-uk.org/education/postgraduate/new_doctor.asp

²² Good practice [http://www.gmc-uk.org/about/reform/Framework%204%203%20\(post%20Council%20May%2008\).pdf](http://www.gmc-uk.org/about/reform/Framework%204%203%20(post%20Council%20May%2008).pdf)

²³ 2008 PMET Review <http://www.pmetb.org.uk/index.php?id=stateofpmet>

²⁴ Documentation on the Foundation programme. <http://www.foundationprogramme.nhs.uk/pages/home/training-and-assessment>

²⁵ Modernising Medical Careers. www.mmc.nhs.uk

²⁶ Documents relevant to foundation training, including the Rough Guide to the Foundation Years <http://www.foundationprogramme.nhs.uk/pages/foundation-doctors/key-documents>

²⁷ Foundation training structure <http://www.medicalcareers.nhs.uk/SpecialtyPages/Medicine/CoreMedicalTraining/Pages/default.aspx>