Physicists and Outreach: Implications of schools physics outreach programmes from the perspective of the participating physicists

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Declaration

I, Charlotte Thorley, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Mum, Dad, thanks for keeping me company when I needed you and always being there.

Dan, you help me to achieve my potential, and I love you for it. Thank you.

Abstract

This thesis examines physics outreach activities from the perspective of the participating physicists. It explores the nuances of physics outreach to school audiences in the context of wider outreach and public engagement agendas for higher education. The study employs mixed methods, comprising an electronic survey and case studies. The case studies follow audiences through nine physics outreach activities that are observed, complemented by semi-structured interviews with the physicists that took part in the activity after the event. Physicists' perceptions and understandings of their audience, and the ways in which the audience are recruited, are shown to be crucial factors in delivering successful outreach activities. Parameters for successful outreach from this perspective are determined, and recommendations made for how such indicators might be developed further by outreach programme managers and influencers such as the Institute of Physics. Obtaining the data needed for this study was only made possible through links to the growing networks of outreach professionals in this field, and the positive impact of such roles was made clear by the participating physicists. The findings of this study will be used to influence physics schools outreach practice, and have relevance to other subjects and audiences.

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List of Abbreviations

AAAS	American Association for the Advancement of Science
CPE	Centre for Public Engagement (QMUL)
EPS	European Physical Society
FOP	Foundations of Professionalism
HEA	The Higher Education Academy
HEFCE	Higher Education Funding Council of England
HEI	Higher Education Institution
HE STEM	The HE STEM programme
IFS	Institution Focussed Study
IOP	Institute of Physics
OFSTED	Office for Standards in Education
PE	Public Engagement
QMUL	Queen Mary University of London
REF	Research Excellence Framework
RCUK	Research Councils UK
SEPnet	South East Physics Network
SOSN	Schools Outreach Support Network (IOP)
STEM	Science, Technology, Engineering and Maths

Chapter 0: Reflective Statement

0.1 Introduction

This thesis is a consolidation of my approach to professional practice. I work in public engagement, encouraging university staff and students to engage a broad range of publics with their work, be it research, teaching or our day-to-day operations. This is an emerging profession, building on earlier developments in support structures for science communication but informed by the methodological approaches of the arts, humanities and social sciences around cocreation and participatory research. As such I consider it a duty to take an engaged approach in developing my own practice; this enables my work to be well targeted and better understood by those I work with, whilst also allowing me to better understand the impact my work might have. It is with these thoughts in mind that I undertook the EdD programme, intending to improve my understanding of the impacts of my work at the same time as demonstrating the value of my professional experience in the area of physics outreach. This reflective statement outlines my learning journey into and throughout the EdD programme.

0.2 Developing a career in an emerging profession

Like many of those working in public engagement, my background is in science and science communication. By the end of my four-year MPhys in Physics with Astrophysics I had developed a desire to broaden my interests. Despite the astrophysics specialism of my degree, I included an inter-departmental condensed matter research project in my final year, working on the practical, and in places qualitative, elements of a study being modelled in the mathematics department and developed for application in the medical school. I quickly grew bored of being referred to as a ‘rocket scientist’ by others involved in the project, and began to realise that there were significant issues with the public perception of physics, even in those from other seemingly similar academic disciplines. With this in mind I started volunteering at the Manchester Museum, developing educational materials to bring out the maths and physics in its

anthropological and cultural exhibitions. This lead to my particular focus on informal education; I subsequently achieved an MA in Art Gallery and Museum Studies, volunteered with the university widening participation programmes and then was offered my first full-time job, delivering schools outreach activities for the independent charity SETPOINT Greater Manchester[1].

I have provided this background to show the opportunistic nature of a career in science communication. From SETPOINT I moved to the Royal Society[2], and then onto SEPnet[3] (the South East Physics Network), a network of universities with a focus on physics, where I became Director of Outreach. By the time I started my EdD and the first Foundations of Professionalism (FOP) Course, I had been in post at SEPnet for two years, managing a network of outreach officers, each of whom had a unique career path and no obvious way to develop their careers further. Like me, their paths were opportunistic, and my concern for all of our futures in this emerging profession caused me to focus my FOP work on developing a framework for progression for these roles. I was struck by the concept of 'third space' presented by Celia Whitchurch (2006, 2008), immediately associating these outreach roles as being third space professionals, caught between traditional academic and professional service roles within their universities. I explored this concept as a way of understanding how outreach practitioners might develop professionally, particularly the way that the audience, in this case schools, influences outreach officer roles. By stopping to consider what is 'professional' about my role and those who worked for me, I realised that I expect my teams to carry an inherent understanding of, and empathy for, both the publics they generate content for and the academics they are supporting or including in their work. This is a large thing to ask of them, and not easy to include in a recruitment process. Consequently, I concluded that as the manager of those in outreach roles I have an obligation to make explicit their requirements to develop understanding of both audience and academics, and support them as much as possible in developing skills in this area.

I also became more able to understand the sources of tension in our roles: the third space concept helped me to consider where our roles were positioned in our

[1] Now Greater Manchester STEM Centre http://www.stemsalford.org/
[2] https://royalsociety.org/topics-policy/education-skills/
[3] http://www.sepnet.ac.uk/outreach/

organisations, and how without structure this might lead to me and my staff feeling exposed or under supported. Outreach roles are pulled in many directions depending on their funding, institutional priorities and personal drivers. All of this is pertinent now, when bodies such as the British Science Association and Institute of Physics (IOP) are seeking ways to professionalise science communication and outreach. My concern remains that without understanding the tensions these roles are under, and resolving in advance the tensions that belonging to multiple professional bodies will cause, the outreach officers will have reduced quality of work and enjoyment. This concern drives my desire that this EdD work is profiled not just in research papers, but also in practical guidance for the learned societies and funders of outreach programmes to enable wider support for the outreach officer positions.

0.3 Different perspectives on outreach and engagement

Throughout my career I have needed to evidence the reasons for, and success of, outreach programmes to a variety of stakeholders including funders, management or steering boards. Such groups are often distant from the practice of outreach, yet I have often found that those people involved have an inherent belief that they know what is best for science education, based on their own experiences of school or having seen outreach delivery. These stakeholder groups are often made up of senior scientists who, due to experience, particularly value the structures and qualifications used in their own fields. This perspective can be limiting; in assuming a position of knowledge, and therefore power, the stakeholder becomes blinded to the value in learning from wider networks or other projects. For SEPnet, this also meant that the management groups had more confidence in, and gave more praise to, those staff holding doctorates than to those of us who did not.

As a consequence, my second motivation in taking on the EdD programme was to prove to myself, and to those involved in these management groups, that my professional experience and knowledge makes me an expert in this area. This, along with the developed understanding of the stakeholders involved in outreach afforded to me by my FOP work, shaped my activities for Methods of Enquiry 1 and 2, where I proposed,

designed and tested a survey- and interview-based study of physicist perceptions of outreach. These methods eventually became the basis for this thesis, and this testing phase allowed me the time to establish my understandings of different methodologies and analysis methods. Through this activity I also began to take on the role of researcher, something I had not done for some time. Importantly, it was during this phase of my studies that I questioned my own understanding of how knowledge is established, and in doing so clarified how I might substantiate my understanding of scientists and outreach in a way that might be shared and adopted by others.

This process made me question a lot about my own practice, and I realised that I carry prejudices and assumptions into my work as much as anyone else does. In order to better assert the quality of different approaches to outreach it is necessary to understand more about the values of those you are working with. This was the essential piece of learning I took from my Institution Focussed Study (IFS). Having taken on a new role as Manager of the Centre for Public Engagement at Queen Mary University of London[4] (QMUL), supporting all research areas in their engagement work, I found myself needing to learn rapidly about a much broader set of interests than I was used to in physics outreach. This new role had been achieved in part due to my research interests in academics undertaking public outreach activities. Accordingly, I evolved my previous work on establishing the perspectives of physics academics on outreach to suit a broader range of academic backgrounds and wider understanding of public engagement. The process was enlightening, and pushed me to challenge my conceptions of research, engagement and management processes, whilst also helping me to meet a significant reporting requirement for the grant funding used to support the Centre.

0.4 Consolidating learning and practice

The culmination of all these strands is this thesis. After completing the IFS, I realised that I wished to focus the remainder of my efforts back on physics outreach, the area I had most experience in but also where I was most excited about making a difference. In

[4] http://www.qmul.ac.uk/publicengagement

some ways this piece of work releases me of a burden I have carried throughout my career. Never quite feeling fully qualified and not in an established profession, perhaps lacking some of the social capital that would allow me not to care about these facts, I have sought over the years to validate my experience and knowledge and to gain verification that my approaches and processes are methodologically sound. In essence, I was seeking reassurance that my opinion is worth listening to. Working in an academic environment means that colleagues are used to pushing forward their own opinions, and I have sought to establish my own voice in this arena. By bringing the focus back to physics outreach, but leaning on my learning from the wider arena of public engagement, I have been able to provide an informed perspective on outreach purpose, drivers, delivery and evaluation that has the potential to be of both theoretical and practical use to the sector.

0.5 Summary

In undertaking the EdD programme I have developed my research skills and found a research approach that I think is most appropriate to someone who manages outreach and engagement programmes, as summarised in figure 0.1. Through this work I have retained my association with physics, physicists and outreach, whilst also developing my understanding of wider university public engagement and research cultures. I will gain the qualification I desired and this will act as a signal to those I work with that I am sufficiently expert that they should listen to me; at the same time I have also grown into my career in a way that means such a signal is now less necessary. I am pleased to be working with the IOP and Ogden Trust on ways to enable outreach officers and academics to access my research findings, and hope this will help many people in years to come alongside any publications I produce from this work. I am also certain now that my next career step should be in a more science-focussed environment; whilst I am sure of the importance of public engagement in all subjects, science will always where I am most effective and passionate. As this thesis suggests, making the most of this passion will enable me to balance other pushes and pulls on my time, enable me to enjoy my work, and help others to the best of my abilities.

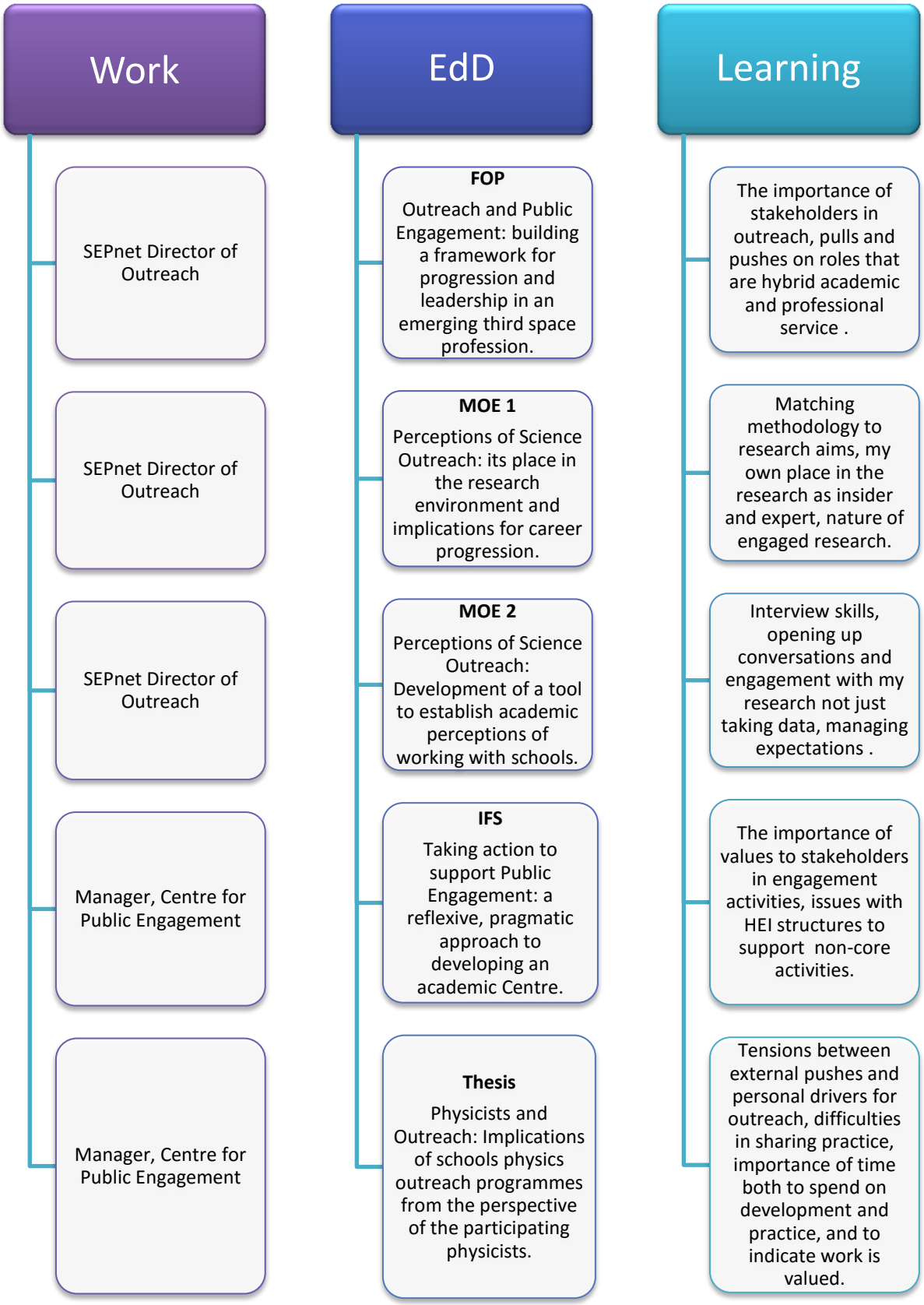

Figure 0.1: Overview of my EdD learning journey

La Comedia, Inferno XXVI, vv. 112-120

"O frati," dissi, "che per cento milia
perigli siete giunti a l'occidente,
a questa tanto picciola vigilia

d'i nostri sensi ch'è del rimanente
non vogliate negar l'esperïenza,
di retro al sol, del mondo sanza gente.

Considerate la vostra semenza:
fatti non foste a viver come bruti,
ma per seguir virtute e canoscenza."

(Dante, 1320)

"Brothers," I said, "who through a hundred thousand
Dangers at last have reached the occident;
To this short vigil which is all there is

Remaining to our senses, do not deny,
Experience, following the course of the sun,
Of that world which has no inhabitants.

Consider then the race from which you have sprung:
You were not made to live like animals,
But to pursue virtue and know the world."

(Translation by Sisson, 1980)

Chapter 1: A study of physicists and outreach

1.1 Overview of the thesis

This thesis examines physics outreach activities from the perspective of the participating physicists. For a number of years, my work has involved encouraging physicists to work with the public, particularly schools, based on the assumption that this will add to the learning experience of the young people in the audience. As I have progressed through my career, as discussed in chapter 0, I have become increasingly aware that such activities are undertaken without serious consideration of the potential value to, or impact on, the participating physicists.

For many physicists, outreach is an additional activity on top of their existing workload and interests, and so those who manage outreach programmes must become adept in choosing arguments to convince physicists to take part. Common examples might include making reference to the impact agenda, or the potential for increased student recruitment or widening participation. In choosing these arguments outreach managers make assumptions about the physicists' perceptions of outreach. At the same time the physicists make assumptions about the nature of outreach and the audiences being targeted. I believe that better understanding of all of these perceptions could improve the management and delivery of physics outreach for all stakeholders: programme managers, audience, and participating physicists.

1.2 Research question

Accordingly, this thesis presents an exploratory study of physicists' perceptions of outreach, and my interpretation of what these perceptions mean for those taking part in or managing physics outreach programmes. My overall research question can be stated as: *What are physicists' perceptions of outreach, and how does this impact on their participation in and delivery of outreach?* Within this there are three sub-questions:

1. What are the contexts within which a physicist takes part in outreach?

2. What does successful outreach activity look like to the physicist, and how does this relate to what successful outreach looks like to teachers, school students and funders?
3. What can we take from the above to help prepare physicists for their outreach experiences?

These sub-questions have the potential to inform future outreach practice for all scientists, not just physicists. Some findings may be subject-specific; others will likely be transferable to other sciences, and possibly other research disciplines.

1.3 Physicist perceptions of outreach

The following chapters present a mixed-methods study that explores physicist perceptions of outreach, with discussion of the methodology and methods given in chapter 3. In chapters 2 and 4 I look at the wider contexts of physics outreach, through a review of the literature that has informed my work (chapter 2), and a UK-wide survey of physicists that builds on previous studies of scientists' participation in outreach and public engagement (chapter 4). Chapters 5 and 6 present the findings of a series of case studies looking at individual incidents of physics outreach through activity observations, and subsequent follow-up interviews with the physicists involved in those activities. Finally, in chapter 7 I bring all of these elements together for my concluding discussions, looking at how physicist perceptions of outreach influence their participation in, and delivery of, outreach and engagement activities.

Chapter 2: Literature and context

2.1 Overview

Leaning heavily on my professional experience, in this chapter I review the literatures I have encountered throughout my career, that have shaped my development and delivery of outreach programmes, and so consequently provide the context within which my study is framed. Academic publications in this area, and that of wider public engagement, can be difficult to locate because of the wide range of research areas they are situated in (Facer et al. 2012, Wellcome Trust 2012b), but there are many other literatures that can be considered to relate to my study, in particular grey literature from the various government bodies, learned societies and universities active in the provision or management of STEM outreach. Each of these perspectives brings a different set of influencers to play on the development, delivery and management of outreach activities.

Over the last ten years I have worked in a range of organisations that support STEM outreach. As described in chapter 0, I have held roles responsible for the delivery of science outreach through to strategic leadership for public engagement in all research areas. Each time I have moved role I have had to reposition my work to account for the different ways in which policies and practices are enacted locally and nationally, and the consequent ways in which this could affect me and my team. I present here a series of syntheses of the literatures that were most influential in shaping the physics outreach and researcher development programmes I have worked on. Through these discussions I establish the factors, enablers and constraints that were most pertinent in shaping my work, and that I think now, on reflection, are in play no matter what type of outreach a physicist, or perhaps any researcher, is involved in.

2.2 A brief history of physics outreach in the UK

For many years now the numbers of young people opting to continue studies in STEM subjects, especially physics, has been an issue of concern (Smith 2004, Royal Society

2008). In 1997 the incoming Labour government requested a series of reports to look into this (Council for Science and Technology 2000, House of Commons 2002, Sainsbury 2007), not least of which was *SET for success: The supply of people with science, technology, engineering and mathematics skills* (Roberts 2002), in which Roberts identified a role for practising scientists to engage more closely with the public to raise the profile of science. This sentiment was echoed in subsequent reports commissioned not just by government but industry and charitable bodies such as RCUK and the Gatsby foundation (Smithers and Robinson 2006, 2007, 2008, Wakeham 2008) with a specific focus on physics. These reports increased the expectation that STEM researchers, particularly physicists, will actively engage the public.

The policies outlined above also informed the development of a new suite of school science courses such as the Applied Science GCSE, kick-started a wave of growth in STEM providers and engagement activities, both independent contractors and managed programmes such as the SETPOINTs and later STEMNET[5], followed by the introduction of Science Learning Centres and the National STEM Centre[6], bodies which provided subject specialist continuing professional development for teachers. In parallel, concerns about raising aspiration in young people to attend university, particularly in STEM subjects, saw the development of widening participation programmes to augment those already being offered through schemes such as AimHigher in 2004 (NFER 2009). This period of growth in the STEM agenda was maintained until next change of government, but changes continued throughout, and projects came and went, such as the HE STEM programme[7] and *Science: So What? So Everything*[8]. HE STEM was of particular note to HEI outreach programmes, working both through learned institutions to deliver national programmes and through individual HEIs and regional hubs, aiming to raise the aspirations of young people with respect to STEM subjects at university, taking a subject-specific approach to widening participation (CFE 2013, HE STEM 2009).

[5] http://www.stemnet.org.uk/about-us/
[6] https://www.stem.org.uk/
[7] http://www.hestem.ac.uk/
[8] http://tna.europarchive.org/20100630051843/http://sciencesowhat.direct.gov.uk

HEI participation in, and delivery of, outreach activities is often accepted as good practice just through the virtue of existing, though these activities often sit outside of national frameworks for classroom enhancement and enrichment such as the Institute of Physics' *Stimulating Physics Network* (Babcock 2011). Developed as part of the HE STEM programme, *Stimulating Physics* continues to this day and is a programme of teacher-led interventions for schools and CPD opportunities for teachers. Whilst the chemistry (*Chemistry for Our Future*) and mathematics (*More Maths Grads*) equivalent programmes included significant national programmes of student and staff outreach, the IOP preferred to concentrate the physics programme on teacher-led activities, in part due to concerns of quality control in HEI led outreach activities. This left a gap in provision for networks of support for physics outreach, so when offered HEFCE funding to support vulnerable subjects, the SEPnet consortium included a significant outreach programme in their plans as part of their measures towards increasing undergraduate recruitment to physics, and nationally there has been an increase in university physics departments seeking and providing support for outreach activities.

The current government continues to acknowledge the issues with recruitment into STEM, particularly girls (National Audit Office 2010, DFE 2014), and so whilst funding to most of the schemes outlined above has now ended, in 2014 the Department of Education introduced their own *Your Life*[9] campaign to continue the work in this area. Continued investment in physics outreach by HEIs and the Ogden Trust means that increasingly physics departments are host to hybrid professional and academic roles to manage such programmes.

2.3 What schools want and need from outreach

Whilst scientists were being encouraged to take part in outreach activities, schools were in parallel being encouraged to involve scientists or science communicators in the opportunities they provide for their students. From as early as 1992 regional SETPOINTS offered delivery of STEM enhancement and enrichment activities to

[9] http://yourlife.org.uk/

schools alongside a brokerage service, linking schools to relevant programmes such as STEM Ambassadors, Young Engineers, CREST or Nuffield Bursaries. As national funding changed, and STEMNET and STEM contracts were introduced, this brokerage became a stronger focus, with directives coming from DIUS, the Department of Innovation, Universities and Skills as a response to the *Science & Innovation Investment Framework 2004-2014* (HM Treasury 2004, 2006), and subsequent *Vision for Science and Society* (DIUS 2008) and from the Department for Education to support *Every Child Matters* (DFE 2003) and subsequent *Children's Plan* (DCSF 2007), to ensure that every child be given the opportunity to participate in such an offering. These lead to documents such as the *STEM Framework* (National Science Learning Centre 2008), which included enhancement and enrichment as a key action for good science education provision, seeking the specific outcome of:

> more opportunities for learners to meet working scientists and technologists to help them both learn in a real-world setting and better inform their life-choices.
>
> (Ibid., p. 5)

Later the OFSTED (Office for Standards in Education) report *Successful Science* (OFSTED 2011) highlighted the inclusion of science enhancement and enrichment activities as a marker for good science teaching standards. This requirement can be interpreted in a number of ways, such as teacher-led science clubs, field trips or visits to science museums, or visiting science shows, as well as the inclusion of activities that might be considered to be outreach from universities.

Access to such activities is not evenly distributed; at the time I took up the role of Director of Outreach at SEPnet two secondary schools were currently receiving 30% of the network's total outreach delivery. These schools were both in a position of privilege, privately-run with significant continued income from investments portfolios, each with their own sixth-form, they both had specialist physics teachers and offered triple-science options at GCSE. Whilst for some schools the pressure of external drivers for enhancement and enrichment, such as the *Successful Science* recommendation, pushed them to start including such elements in their provision, there were also many others who had extensive history in including such approaches. National STEM organisations

responded to these policies in efforts to try and help teachers in implementing the recommendations and to navigate the increasing number of opportunities being offered.

The STEM agenda brought with it a wave of activity that might to some look like the beginning of provision, outreach to schools, and schools partnerships with universities can be traced back to the foundations of such institutions, and programmes of activity have existed, somewhat sporadically and without such national reach, for considerable time, for example the RI Christmas lectures founded in 1825, or the Royal Society Partnership Grants which launched in the early 1970s. What was new about the activities in this wave of the STEM agenda was the suggestion of equal access; widening participation sits at the heart of these programmes and was a condition of the funding supporting them.

2.3.1 Choosing an intervention

In choosing an intervention for the students a school teacher must balance multiple factors, including curriculum and syllabus requirements, timetabling, cost and the potential impact of the activity on the students (Johnson 2014). Most evaluation of outreach activities is carried out with this latter factor in mind, seeking to evidence how the student might have improved their ability or increased their aspiration, changing their own identity trajectory, through relation to a specific area of STEM (for example Laursen et al. 2007, Kurtines et al. 2008, Polman and Miller 2010, Dabney et al. 2011) and is of particular importance to those seeking to increase participation of girls in physics (DCSF 2009, Calabrese Barton et al. 2013, Macdonald 2014). This approach is also extended in some instances to look at how projects might defend against student self-perceptions of loss of ability, and consequently aspiration, a key factor in students dropping out of physics courses (Johannsen et al. 2009).

As mentioned at the beginning of section 2.3, enhancement and enrichment can take many forms, and there have been various attempts to try to corral this information to make choosing an intervention easier for the teacher, through online portals such as the STEM directories (Royal Institution 2010) or brokerage services such as those offered by STEM contract holders. Many activities are offered in situ at cultural venues or other

education establishments, offering opportunities to use novel equipment (Quin 1990), explore a particular environment or work in an environment that is unfamiliar, challenging the class to develop new behaviours and identities (Braund and Reiss 2004). Most widening participation programmes offer opportunities bring students onto a university campus as one way to help the students envisage themselves at university in their future; inclusion of this mode of delivery for physics and wider STEM outreach has been endorsed through the Higher Education Academy (2007) and HE STEM (2010) programmes. However, taking a scientist and/or an activity out into schools can alleviate issues with costs, teacher cover and parental permissions, as well as timetabling issues so is a popular option for those departments trying to expand the reach of their outreach programmes (Harrison and Shallcross 2007, Thorley 2011). In these cases, the desire of the HEI to reach new audiences also means they will be willing to spend more time eliciting the attentions of a particular school, making the arrangements easier for the teacher; as such schemes start to reach capacity this relationship changes, with the schools needing to make more efforts to stay involved, or potentially no longer receiving activities because they have already been reached.

2.4 What is outreach?

The definition of outreach that has underpinned my career is that offered by the then Department of Innovation, Universities and Skills (DIUS), later Business, Innovation and Skills (BIS):

> **What is outreach?**
>
> Many organisations encourage employees to become involved with initiatives in their local community or educational establishments. The aim is, generally, to give something back to the community, but it also promotes the organisation and may change stereotypical images of the organisation and/or profession.
>
> (BIS 2011)

The BIS website makes specific reference to schools outreach, identifying schools as a significant audience in terms of the impacts that can be made:

Outreach to schools and colleges

> Primary, secondary schools and colleges are central to motivating and enabling students to pursue higher education and in their choice of career. Many organisations are keen to bring the excitement of their sector or profession to school students. These employees can provide positive role-models for young people and can challenge traditional perceptions and stereotypes.
>
> (Ibid.)

These definitions were made available by late 2004, and were supported by extensive existing practice in the organisations I was first introduced to outreach by; the University of Manchester, where I volunteered as part of their widening participation programmes, and SETPOINT Greater Manchester who offered me my first paid role in outreach delivery. Through these roles and interactions with the local Museum of Science and Industry, now known as MOSI, and Manchester Museum, I developed a clear set of boundaries around terminology in this area. 'Outreach' represented work carried out on behalf of institutions or employers, could take place in a variety of settings but normally not the site of the organisation I was representing, included content that was inspirational rather than having specific curriculum delivery included, often involved demonstrations, and was free-of-charge at the point of delivery, i.e. it did not cost the schools I was working with anything to participate, but they needed to cover their over travel or expenses if involved. The aim of this work was to raise aspirations and enthusiasm for STEM, and all of my work was with schools. SETPOINT offered a range of options for schools to pay for activities, and these were our 'enhancement and enrichment' offerings; more closely tied to the curriculum these sessions were designed to augment classroom teaching, nearly always happened in school, provided more hands on opportunities for the students, and in the case of work with primary schools often made up a significant amount of their delivery of some STEM subjects.

Over time these boundaries have needed to be flexible, and I have tended to evolve my terminology to suit the particular project I was working on. Tension arises for subject specific outreach programmes because of pre-existing widening participation programmes where their approach to outreach is about promoting higher education rather than a specific subject; this link to widening participation can create the perception that outreach is always work targeted at schools, rather than schools being

one specific audience. A second challenge is over payment; the SEPnet programme was grant funded, with the requirement to become sustainable over time. One option to create this sustainability was to introduce charges to schools for their participation in programmes, something I resisted and to this date has not been introduced; instead other grant sources, HEFCE and OFFA funding has been used to cover costs.

A recent survey of the science communication sector has proposed a new definition for outreach:

> Outreach: a one-way discourse, in which scientists communicate their research to the general public, with particular focus on school children and young people.
>
> (Illingworth et al. 2015, p.10)

This, at its core, is similar to the BIS definition but more specific about the style and content of delivery. My experience of outreach is that often programmes of managed or collaborative outreach, or those involving mass delivery such as those from the HE STEM programme (for example RSC 2016 or More Maths Grads 2010) or SEPnet (HE STEM 2012), are delivered by trained ambassadors or communicators, and so are much more likely to be covering the fundamentals of a particular research area rather than focussing on the research of an individual. That is not to say that content is not augmented by the research or work interests of the individual delivering the session; in fact this model is the main premise for the involvement of student ambassadors and other trained representatives in the programmes just mentioned, and of engineering ambassadors in schemes such as the *STEM Challenge* or *Making Knexions* events that are part of the Young Engineers programme (Young Engineers 2016). Such activities are all designed to be interactive, and to involve the young people taking part in some hands-on activity to complement talks by the visiting scientist; as such I am also interested to look further into the notion of 'one-way discourse' in the definition above.

Not all outreach is interactive in this way, and public talks are the most common form of engagement activity cited by scientists (Royal Society 2006). Most HEI outreach activities are designed with a specific target audience and message in mind, or else to suit the deliverer, using a format that is comfortable and requires minimum effort. Although there are many guides to help with targeting and delivery of STEM outreach in general, only a small body of evidence exists (Laursen 2007, Kapon et al. 2009,

Webb et al. 2012) in supporting critical development of such programmes to ensure benefits for all stakeholders, audience and participating scientists.

2.4.1 Outreach, public engagement and informal education

So far in looking at definitions of outreach I have not explored in any depths the connection to public engagement or informal education. Definitions of public engagement remain very fluid, and the term means very different activity to researchers working in different areas. The NCCPE (National Coordinating Centre for Public Engagement) defines public engagement as:

> Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit.
>
> (NCCPE 2014a)

This definition might be considered to be inclusive of outreach, although the 'two-way process' described here is in conflict with the 'one-way discourse' outlined by Illingworth et al. above. Experience of working with researchers at QMUL tells me that for some subject areas, particularly the physical sciences, the definitions of public engagement and outreach are often blurred, with each term being used interchangeably and not always well understood (Thorley 2014).

Informal education is a term not commonly used by HEIs, yet the activities it refers to have great overlap with outreach. In a recent *Review of Informal Science Learning* two broad categories for informal science learning are offered, which read:

> The first focuses on learning that explicitly enhances formal science learning and takes place in more formal environments. It is not entirely voluntary (e.g. a school trip to a science museum) but it is categorically different from formal, classroom-based science learning. For these activities the target audiences are schools and teachers, who generally only value this form of science learning if it is or can be related to the curriculum and engages their students.
>
> The second category is much broader and covers activities that are voluntary and that take place in formal settings (such as museums), informal settings

> (such as the home) and places in between (such as community centres). Within this framework, providers deliver several activity types to a range of audiences.
>
> (Wellcome Trust 2012b, p.12)

Within these two categories both schools outreach and wider outreach can be situated, particularly if they are delivered on-site at a university or off-site, in a neutral location. However, despite the growth in programmes described above, the accompanying analysis of informal science providers (Wellcome Trust 2012a) suggests that HE is not a significant sector in the provision of informal science learning when compared to science festivals, science and discovery centres and museums; despite this they found universities to be at the heart of the informal science community as shown in figure 2.1. Although this is described away in a footnote as possibly being due to the *Beacons for Public Engagement* initiative, I strongly believe that the programmes I have described in sections 2.1 and 2.2 show that universities have been at the heart of such a movement for some time now. Outreach or informal learning is inherent to both national widening participation programmes and subject-lead outreach programmes to increase participation in sciences. Many of the other activities happening through broadcasters, festivals, field centres, museums and learned societies are supported in the development and/or delivery of their programmes by academics who are employed at universities; a good example of this is the Cheltenham Science Festival, where university-based scientists are included in the governing committees, the delivery of individual talks and activities, and media work related to the event. The role of the university in the informal science education sector should not be underestimated.

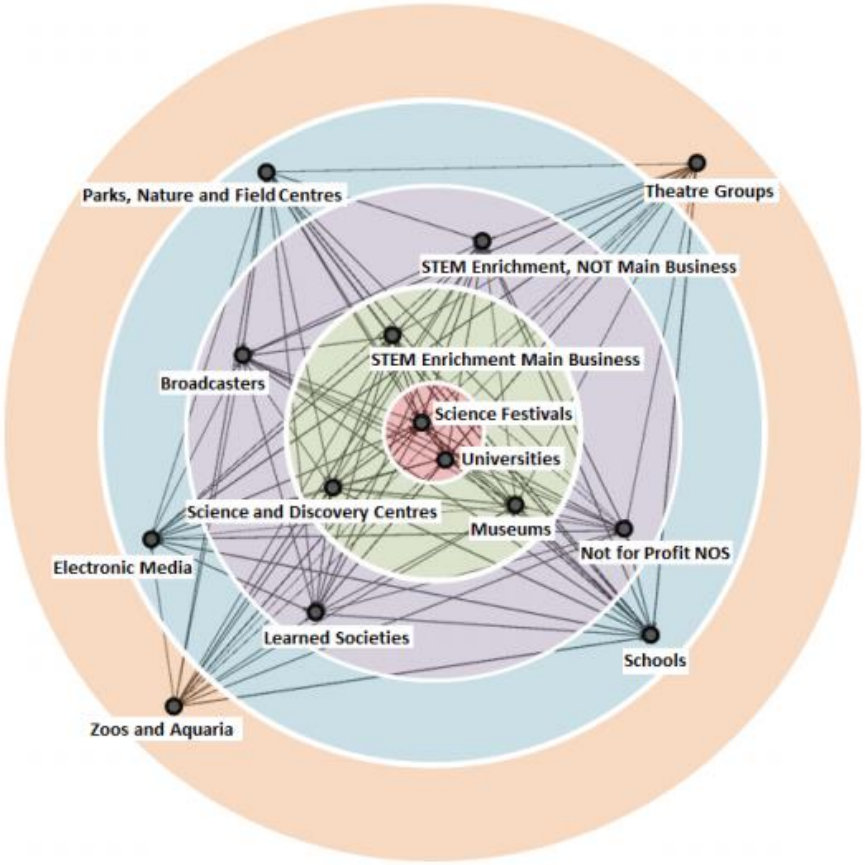

Figure 2.1: Quantity of interactions among UK science education sectors – greatest interactivity in the middle. Taken from *Analysing the UK Science Education Community: The contribution of informal providers* (Wellcome Trust 2012a, p.29)

2.5 Participation of scientists

In sections 2.2-2.4 I have demonstrated the range of activities that a scientist might participate in under the umbrella of 'outreach', noting that often this term is taken to mean outreach to schools. This sets the context within which outreach occurs. Now I will go on to outline the factors that affect the participation of scientists in outreach activities, looking at how and why scientists get involved in outreach, and the systems that measure and support their activity.

2.5.1 The personal nature of physics communication

Over the years I have been lucky enough to work with a lot of very engaged physicists who all see the value of communicating their work to the public. Working with these physicists, and in reading around the area of science communication as defined by Burns et al. (2003), has highlighted the personal nature of participants' knowledge and activity in this area. Jon Butterworth, particle physicist at UCL and CERN, blogger for the Guardian and generally media-friendly scientist talks at length in his recent book (Butterworth 2015) about the history of science communication from his perspective, much as I have done here with my history of physics outreach. In compiling his story Butterworth assumes that the current interest in science communication activity started at the same time as his interest in it. His first encounters with the movement are around the opening of the LHC, which has particular importance to his work at CERN, and the parallel movement of scientists to support Simon Singh in the defence of his article about chiropractors (Singh 2008), and these interactions shape both his activity, and his understanding of the meaning and purpose of science communication.

At the other extreme Peter Kalmus, emeritus professor at QMUL gives a talk to local physical societies on his own personal journey into science communication, starting with the end of the Second World War (Kalmus 2009) and the need to improve public perceptions of research into areas such as nuclear physics that had developed negative connotations because of how they had been employed in the war. In this talk Kalmus acknowledges the importance of the Faraday lectures at the Royal Institution and the culture of science communication that already existed to his own journey.

Personal journeys and identities are inherent to science communication even where personal journeys into communication are less obvious. Jocelyn Bell-Burnell and Athene Donald are often asked about their journeys as women physicists, and their consequent work in supporting initiatives to encourage inclusion for girls in physics. Jim Al-Khalili and Brian Cox have become the public faces of physics over the last few years without needing to explain their own journeys into communication, and instead provide an approachable personality for a subject area that is often considered remote or difficult to access. Indeed, much praise has been afforded to the 'Brian Cox effect' (Vasagar 2011, Paton 2013) for increasing the number of applications to undergraduate

physics, although it has elsewhere been acknowledged that this surge was most likely due to a number of factors (Ghosh 2011), including the extensive outreach and widening participation programmes outlined earlier in this chapter.

One indicator of, and contributor to, the success of science communication activities in increasing the popularisation of physics has been the American sitcom *The Big Bang Theory* (Townsend 2011). Featuring a group of male early career physics researchers, and an engineer, and their beautiful female next door neighbour the show explores the lives of the group and the relationships they form. This show is perhaps the first time that physicists and their day-to-day work have featured so prominently in a cultural offering that was not to do with a fundamental discovery or particularly high-profile physicist. I mention this in so much detail to enable me to introduce one particular episode, 'The Contractual Obligation Implementation', a still from which can be seen in figure 2.2.

Figure 2.2: A still from The Big Bang Theory episode entitled 'The Contractual Obligation Implementation'. Three of the series' main characters (from left to right Howard, Leonard and Sheldon) are delivering outreach to a group of girls in high school with the aim of encouraging them to consider a career in science. Photo by Michael Yarish © 2013 Warner Bros

In this episode the main characters Leonard, Sheldon and Howard are discussing their contractual obligation to serve on a university committee. They choose, because Leonard states that it is a cause he believes in, to participate in a programme of encouraging more women to pursue a career in the sciences. They decide to provide an intervention to girls in middle school (aged 11-14), and this is where we find them in the transcript of a scene below:

> *Scene: A classroom.*
>
> **Leonard**: Okay, who's ready for some science? Me, too.
>
> Okay, I am Dr. Leonard Hofstadter. I am here with my friends Dr. Cooper and real-life astronaut Howard Wolowitz, and we are going to show you girls how cool a job in science can be.
>
> How cool, you ask? Well, how about negative 273 degrees, 'cause that's the temperature at which entropy reaches its minimum value.
>
> Did I just learn something new and have fun doing it? What? All right. So now let's bring out theoretical physicist Dr. Sheldon Cooper.
>
> **Sheldon**: Hello, female children. Allow me to inspire you with a story about a great female scientist. Polish-born, French-educated Madame Curie. Co-discoverer of radioactivity, she was a hero of science, until her hair fell out, her vomit and stool became filled with blood, and she was poisoned to death by her own discovery. With a little hard work, I see no reason why that can't happen to any of you.
>
> Are we done? Can we go?
>
> *Fade to logo screen. We return to the classroom some time later.*
>
> **Howard**: The thing to remember is you can go to outer space, too. I mean, look at me. I went to this very school. Those desks you're sitting in, I was once superglued to one of them.
>
> **Girl**: Did you go to the moon?
>
> **Howard**: No, but I did go to the International Space Station.
>
> **Girl**: Did you fly the rocket?
>
> **Howard**: No, but I was in the rocket. I didn't actually …
>
> **Girl**: So you just flew around? That's kind of like my uncle. He's a flight attendant.
>
> **Howard**: No, I'm an American hero. Your uncle brings people nuts, okay?

> **Leonard**: Alright, alright. Boy, we are learning a lot here, huh? Thank you, astronaut Howard.
>
> Um, I am what's called an experimental physicist, which is super-fun, because I get to test theories and work with lasers. Yes?
>
> **Girl 2**: How did you decide to become a scientist?
>
> **Leonard**: Uh, excellent question. Um, I suppose I've always been into science, you know. My mother and father are scientists, so I was kind of led in that direction. Uh, pushed might be a better way to describe it.
>
> To be honest with you guys, when I was your age, I wanted to be a rap star. Like Snoop Dogg, but with a healthy respect for the police. Yeah, no, sure, you laugh.
>
> [He starts rapping] Just like my mother did. After I confided, I was derided and chided, my mom said I collided. She said my dreams were misguided.
>
> That's just a little freestyle.
>
> (Transcript of *The Big Bang Theory*, Season 6, Episode 18, 2013)

Whilst overall *The Big Bang Theory* portrays the main characters in a sympathetic way, the comedy of the show often relies on them being socially awkward and this scene is typical in that respect. The characters find their interaction with the girls in the class difficult, and Sheldon later remarks:

> I don't know if women in general have been actively discouraged from pursuing the sciences, but it's clear you young women here, today, have been.
>
> (Ibid.)

In the end they resort to calling their less awkward, female, neuroscientist and microbiologist friends to speak to the class. As someone who manages outreach programmes I find this episode somewhat distressing. Well aware of the pitfalls of sending someone who is unsupported and unprepared into schools, I find myself concerned that the characters were not able to find a way to succeed in their outreach endeavours. It seems unlikely that anyone watching it would leave with a positive opinion of physicists or their ability to communicate with the public. The other issue is the way in which outreach is portrayed. Whilst many physicists take part in outreach willingly and under their own motivations, many are tasked to do so by their managers and in these instances need additional support to ensure a positive experience. There is

only a limited body of research into scientist participation in outreach, as I shall now go on to explore.

2.5.2 Motivations and benefits

Understanding what motivates scientists to take part in outreach is essential to encouraging their participation, and it seems that they are motivated to get involved in outreach and communication activities by a variety of factors. In sections 2.1-2.3 I demonstrated the policy pushes that are active in this area; these pushes are supplemented by personal drivers and local factors. Where researchers have sought to explore participation in public engagement and outreach activities, the scientists involved have tended to report their experience positively (Pearson et al. 1997, Andrews et al. 2005, Burchell et al. 2009, Poliakoff and Webb 2007, Ecklund et al.2012, Davies 2013), describing the activity as enjoyable, rewarding, fun or satisfying. Throughout all of these works there is an underlying suggestion of moral obligation to take part in engagement and outreach, made explicit in some reports (PSP 2006b, Matthews et al. 2005). Some acknowledgements are made of personal gain through participation, such as increased profile or completion of a required task (Davies 2013) or improved teaching or communication (Andrews et al. 2005).

Such motivations are part of a complex system of individual behaviour and institutional culture. *Factors affecting Science Communication* (PSP 2006a) showed that scientists would feel more motivated to take part if these benefits were more widely recognised, in this case through the suggested avenues of awards and funding. Jensen et al. (2008, Jensen 2011) conclude that those academics who take part in public activities of this type are also those that perform better academically, but as I will show in section 2.5.3, this association is not perceived by the wider academic community.

2.5.3 Barriers

The same literature that explores scientists' motivations for outreach also has a strong focus on the barriers scientists might perceive to their participation (Andrews et al.

2005, Royal Society 2006, Poliakoff and Webb 2007, Ecklund et al. 2012, Davies 2013). Common to these are concerns over reputation and career, with early career researchers in particular worried that time taken to deliver outreach activity is seen as frivolous by their supervisors (Royal Society 2006, Ecklund et al. 2012), and the wider perception that those scientists who have time to do engagement activities might be considered to do less science or be less rigorous scientifically, something Jensen et al. (2008) describes as the 'Sagan Effect'. Time constraints are the other most commonly reported barrier, reported more frequently by those who are in an environment unsupportive of public engagement activity, even if they have already managed to make time to participate in an activity (Poliakoff and Webb 2007). Whilst the moral obligation to do outreach and engagement is documented as a motivator, such an obligation can become sour when it is expected without management support or reward (De Welde and Laursen 2008, Davies 2013), particularly as it is an activity that might be considered non-essential in an academic environment with significant external pressures, short-term funding and without clear institutional direction.

2.5.4 What does success look like?

As stated in section 2.2, most evaluation of outreach programmes focuses on the outputs with respect to the audience, such as satisfaction, learning or behavioural change, and tends to be written up as grey literature and project reports rather than as research papers. In seeking a more scientist-centric set of success indicators, I have found that evaluations of outreach in research journals still tend towards basic evaluation and surveys of audience members, and are most often found within subject-specific literatures as news articles rather than as academic papers. This diffusion of published works makes it difficult to find quality in publications and for knowledge and practice to be shared (Facer et al. 2012, Wellcome Trust 2012b). The primary concerns of such reports tend to be the reach of an activity through audience numbers and an associated potential for recruitment, or in some cases the demographic breakdown of the audience; these are the indicators being asked for by funders and governance agencies (HEFCE 2007) and which the recent REF process indicates are valued by peers (NCCPE 2014b, REF 2014, HEFCE 2015). Other publications do not make recommendations for others

to take on board, but simply present their approach through a confident review of their activity, an approach of which I too am guilty (for example Harrison et al. 2010, Thorley 2011, Micklavzina et al. 2014). Such sharing through science journals or subject-body magazines can imply 'best-practice' through the authority of the publication and its peer review process, even if there is no robust evidence to suggest it has created significant behavioural or attitudinal change in the audience. It is this category of publication where most scientists engaged in outreach can be found publishing; this suggests the possibility that the majority of scientists are not accessing the best literatures in science communication or education.

Where programmes have adopted social science methodologies to support their evaluations, possible improvements to outreach processes and approaches are typically offered, such as introducing pre- or post-intervention activities through websites or teacher resources (Bruce 1997), using different spaces (Slayton and Nelson 2005) or improved aesthetics of materials and presentation (Bucchi 2013). Improved evaluation of such audience outcomes is recommended by funders and researchers (Wellcome Trust 2012b, Wilkinson et al. 2012). The growth of work in the public engagement sector, rather than education outreach, has opened up discussions around improving scientists' perceived value of two-way interactions and dialogue with the public (Wilkinson et al. 2011, Haywood and Besley 2013) and improved understanding of the public's high expectations of engagement activities (Wilkinson et al. 2012). Education approaches show how activities can be developed to improve audience engagement and learning (Scharfenberg 2010a, 2010b, Wellcome Trust 2012b, Haywood and Besley 2013), seeking increased audience voice and contribution, through questions, comments and interaction to indicate successful engagement.

Whilst scientists' opinions on the indicators they use to identify successful outreach are not well documented, there is evidence that some have concerns about how the quality of outreach and engagement activities will be assured. Some suggest that other bodies, such as the learned institutions or subject organisations, might be better placed to represent science to the public (PSP 2006a, Matthews et al. 2005). Attempts to mitigate these concerns and the issues with practice sharing in the sector have been addressed as part of programmes such as the Higher Education Academy or HE STEM, but as funding wanes any support structure eventually crumbles. An exception may be physics

outreach; the growth of physics outreach programmes indicated in section 2.1 has been mirrored by the development of specific support networks for physics outreach such as the IOP SOSN (Schools Outreach Support Network), open to both physicists and the professional outreach staff working with them. The investments into outreach made through SEPnet and by the Ogden Trust have seen organic growth in communities of practice for physics outreach staff through their associated institutions. However, it remains to be seen for how long these networks can be sustained, and whether their potential benefits can be felt by the wider academic community they work with.

2.6 Informing practice

In sections 2.1-2.5 I have outlined the literatures that inform my practice as a manager of outreach programmes, and shown the major known factors in scientist participation, summarised in table 2.1.This provides the foundation for my own study. Noting the growth in physics outreach programmes outside of nationally managed schemes, and the support networks that are emerging alongside them, it is timely to take a detailed look specifically at physicist, rather than scientist, perceptions of outreach.

Through the lens of my own professional experience, I shall seek to establish whether the factors outlined in table 2.1 are the most significant influences on physicist participation in outreach, and how this manifests itself in outreach practice. Given the remaining uncertainties in use of terminology in this area outlined in section 2.3, I shall seek to establish how UK physicists interpret the term ‘outreach’, and explicitly look at how they see the relationship between work with schools and wider public engagement.

Stated motivation	Perceived benefits	Perceived barriers	Measures of success	Emerging issues
Duty and perceived need for action Enjoyment/fun Personal feeling of reward or satisfaction	Improved communication or teaching skills Personal feeling of reward or satisfaction Fulfilling obligations and making a contribution to external agendas	Time pressures Developing a reputation for being a second-rate scientist Perception that scientists are not good at communicating Lack of reward/appreciation for activity Does not contribute to career development	Reach (audience numbers) Happy customers, basic evaluation Personal gain (skills, rewards)	Lack of shared understanding of outreach; limited access to literatures and resources Lack of practice at sharing outside of networks for outreach professionals

Table 2.1: The factors affecting scientist participation in outreach activities

In particular, I will explore what success looks like from the perspective of the physicist; whilst it has been possible from the studies outlined in sections 2.3 and 2.5 to establish what is most commonly reported as success, it is not clear to me that this is representative of the indicators that the physicists might use to measure the relative success of an activity they take part in.

In the next chapter I will explain how I have developed a pragmatic and engaged research approach that enables me to explore these issues more deeply.

Chapter 3: Methodology and methods

3.1 Introduction

What are physicists' perceptions of outreach, and how does this impact on their participation in and delivery of outreach?

I restate my research question here, at the beginning of this chapter, to reassert the importance of perspective in this study. In chapter 2 I presented the literature that provides the foundation for, and informs the context of, this study, a literature that is heavily influenced by my professional experience. In this chapter I demonstrate how this experience and context have informed my development of a research approach that allowed me to position physicists at the heart of my study, successfully facilitating their contributions to my data, and interpreting these data in a way that is considerate of their circumstances and needs.

3.1.1 Values-driven research

My work is inherently values-driven, as is the case for most people working in public engagement. I believe that research should be accessible by, and accountable to, the public, and that researchers should take responsibility for making their work understandable to the widest possible publics; where necessary researchers or research institutions should work with publics to help them develop any skills they need to understand the evidence presented. Moreover, in line with the recent surge in interest in public engagement (see section 2.2) and engaged research, I believe that research can be improved through the involvement of publics, with the understanding that said publics must be described and defined and their involvement meet a need from their perspective, whether that be enjoyment or co-creating knowledge. As such I consider myself to be an *engaged researcher* (NCCPE 2014c), as, I have striven to involve my target publics in the design, as well as the dissemination, of my study to ensure that the outputs will not only inform my work, but also that of my delivery teams and the scientists and researchers they work with.

3.1.2 Pragmatism and practical considerations

Teddlie (2005) suggests that the heavy influence of the values of the researcher, in choice of topic, design and interpretation, is common in *pragmatist* research. Accordingly, and as is common to my normal ways of working, I have taken an engaged and pragmatic approach to this study. It is my professional opinion that to be engaged you must also be reflexive, prepared to listen and learn at each stage of a process. Adding in the pragmatism ensures I am able to determine a pathway through this that is effective and efficient in terms of delivery and reporting, whilst being methodologically apposite (Bryman 2006, Brannen 2007, Silverman 2010).

In considering the participation of physicists in outreach activities in chapter 2, I highlighted that scientists tend not to engage with the science communication or school science education literature. The perceived barriers to their participation in outreach, such as time pressures and lack of support or reward, are likely also to affect how much resource or effort a scientist might put into seeking out outreach literatures, evaluations or tools. Whilst I will also reflect on these issues when drawing conclusions from my data later on, the issue is pertinent now as I consider the theoretical framework for my research. For this research to have maximum impact, generating new knowledge and to be useful to the publics I am working with, both physicists and physics outreach officers need to inform this research, and engage with my purpose and processes. Through this engaged approach I hope to reach those physicists who might not otherwise have the motivation to seek out help with their outreach activities.

3.1.3 Positioning myself within this research

The growth of physics outreach as an activity within universities has triggered the parallel growth of a profession; outreach officers and managers are now evident in university physics departments throughout the UK. Delivery of physics outreach is primarily undertaken by these professionals and academics, and in some cases supported by the use of student ambassadors. Outreach tends to sit outside of the normal core duties of a physicist, and so physicists engaged in outreach find themselves in a position akin to being a volunteer, although for some there will be significant pressure

on them to participate. For the outreach professionals there can be a tension between their professional roles and their need to maintain status within an academic context. This positioning of outreach between normal academic and professional activities makes it a 'third space' activity (Whitchurch 2006, 2008), as outlined in figure 3.1. Here, Whitchurch describes outreach as a 'perimeter role'; however, she is considering outreach to be synonymous with widening participation here. In the case of subject-specific outreach rather than general widening participation activity, and where academics are core to both content generation and delivery such as is the case for most departmental physics outreach programmes, I would consider outreach to be a truly third space activity.

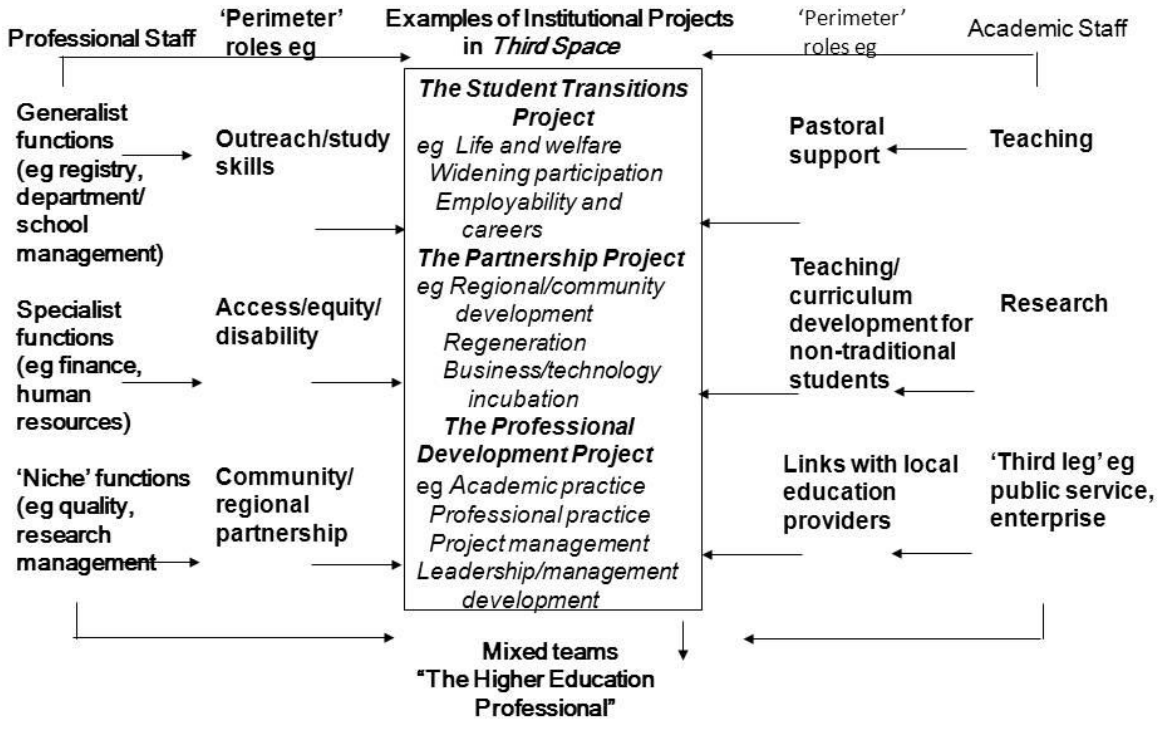

Figure 3.1: 'Third Space' diagram as presented in Foundations of Professionalism course. Published in Whitchurch (2008, p. 385)

Having established physics outreach as a third space activity, this means that the actors involved, physics outreach officers and physicists, are third space professionals, subject to the pushes and pulls of both professional and academic environments. As an engaged

researcher and engagement professional I consider that our work in this space to also be influenced by a third factor, the audience or public, as shown in figure 3.2.

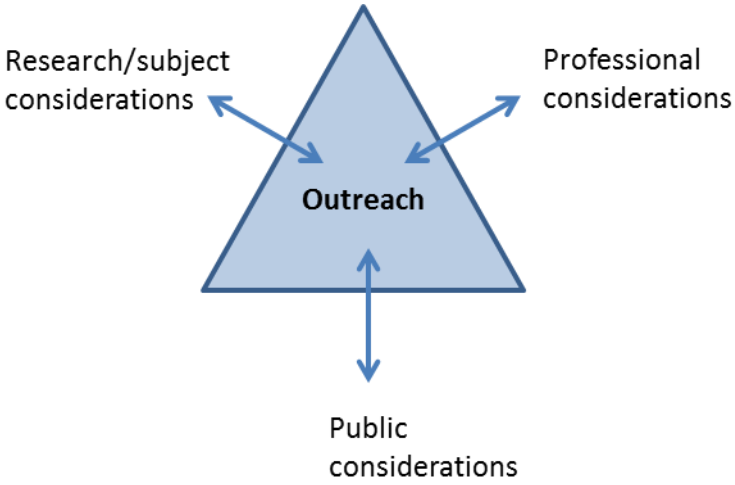

Figure 3.2: A reimagined 'third space' for outreach activity, placing the public as a third parameter for consideration in outreach work alongside that of academic or subject requirements and professional considerations

This then is the space within which my research takes place. As an outreach professional I am already considered an insider (Sikes and Potts 2008) to this space, yet it is expected that I feel the pressures of the influencing parameters differently to how they impact on a physicist. The fourth parameter that is acting on me, that of my role as social science researcher, has the potential to distance me from the outreach officers, and the physicists I am studying, due to the use of unfamiliar language and approaches. This is mitigated by my professional relationship to the population I am studying; Whitchurch describes third space professionals as needing "credibility on a personal basis" (2008, p. 394), and it is my personal credibility with the physicists and physics outreach officers that I have used to enable them to accept the value of this research project.

3.1.4 Bridging a paradigm gap

In section 3.1.3 I have explained why my position within the research is important; one significant factor in this is the relationship between the physicist population I have studied and the types of research approach that enable deeper understanding of the processes and impacts of outreach. I noted in the literature review, as did the Wellcome Trust's *Review of informal science learning* (2013b), that much of the literature around evaluation of informal science programmes is heavily survey based, and not published beyond internal or community facing documents. Where practitioners have found communities of practice to publish within, such as the *Communicating Astronomy with the Public* journal (for example Laird and Christensen 2014), the level of detail and rigour required is enough to promote an approach or share ideas, but not methodologies or a deeper understanding of practice. Looking at the literature, where studies do seek to explore scientist perceptions of outreach and engagement, I see a tendency to present survey data as truth from the outset (Andrews et al. 2005, Royal Society 2006, Poliakoff and Webb 2007, Ecklund et al. 2012, Davies 2013), presenting the responses as truth without acknowledging the contextual factors that must necessarily influence both the responses and analysis. I have experienced this as being a symptom of reporting requirements and lack of resource allocation, but also a reflection on the nature of the people carrying out the evaluation, normally time stretched, and without an evaluation or social science background. There can be a naivety about this approach, an assumption that a basic, formulaic evaluation is in its own right is rigorous research.

The other extreme presented in the literature is those who have taken approaches that distance themselves from their data (for example Jensen and Holliman 2015). This represents to me a mode of science communication research that has moved away from science communication or engagement itself, and seeks to authenticate itself by shifting into the more theoretical spaces of social science. Whilst there can be no doubt of the quality of this research approach, it requires significant understanding of particular philosophical viewpoints; in short, it is not very practical, nor easy to access as scientist who communicates. Such work is more likely to be found, and used, by science educationalists or other science communication researchers than by outreach professionals and scientists. Conversely, the published works of the practitioners and

scientists are rarely referenced by the education and communication research communities, in part due to the lack of development in the thinking that underlies them.

3.1.5 A reflexive, engaged and pragmatic approach

This study is designed to take into account those factors raised in sections 3.1.1-3.1.4; through connection to the bodies of literature in education and science communication an approach is needed that is most appropriate for addressing the research question, yet enables this approach to be understood and valued by the communities of practice I wish to influence. The pragmatic stance implies that through the application of logic and rigour (Alvesson and Sköldberg 2009) it should be possible to find a useful research design for any given situation, opening up any situation to social enquiry (Brannen 2007). Bryman (2006, p.124) describes the pragmatic stance as prioritising "any approach that allows research questions to be answered regardless of its supposed philosophical presuppositions". This viewpoint appeals to me as a researcher; having trained as a physicist who worked with both quantitative and qualitative methods in empirical research, I am driven to find a method that will allow the question to be answered well, but also be reported in ways that can be engaged with by multiple audiences, enabling my work to be repeated or built upon.

Having outlined the frameworks of thinking and beliefs behind this study, I will now go on to show their manifestation in terms of research design and tools.

3.2 Method and design

A multi-strategy approach (Robson 2011) is essential for this piece of work. The performativity issues (Ball 2008) within the academic environment, such as those caused by the REF and access agreements (REF 2014, OFFA 2015), mean that there is increased pressure to justify all outreach work, particularly with reference to institutional targets. It follows that to address my research question effectively I need to look both widely, across as many institutions and career levels as possible, and deeply,

following individual experiences of outreach through delivery and reflection after the event.

Accordingly I have taken a two stage approach. The first stage is a survey of all physicists in the UK working at academic or research institutions, to gather quantitative and qualitative data about their perceptions of, and activity in, outreach, providing a broad context for my work. This is followed by a series of short ethnographic case studies involving the observation of outreach activities and follow-up interviews with the physicists involved. These two phases could be reported separately, but considering them together (Bryman 2006, Botha 2011) provides rich information and understanding whilst avoiding anecdotalism (Silverman 2010).

3.2.1 Survey of physicists

As I have discussed in sections 2.5 and 3.1.4, most work exploring scientist perceptions of outreach has taken the form of surveys; of particular note is the 2006 *Factors Affecting Science Communication* report commissioned by the Royal Society (PSP 2006a, 2006b, Royal Society 2006), where a questionnaire was designed to use with a sample of HEI's to represent the population of research scientists. I have systematically sought other work in this area, finding a tendency towards survey approaches but with smaller cohorts, and mixture of paper, electronic and interview data collection (Andrews et al. 2005, Poliakoff and Webb 2007, Ecklund et al. 2012, Davies 2013, Johnson et al. 2014); some are limited to one institution or to an opportunistic population of contributors to outreach programmes, others use small samples to try to represent a difficult to define population. Each has designed its own tool from scratch, without significant reference to collection or analysis techniques from the other studies despite their shared interests.

3.2.1.1 Questionnaire design

To build on each of these approaches, provide a national context and open up the discussion to as wide a range of respondents as possible, whilst taking a subject-specific

stance on outreach and schools engagement, my survey was conceived as a census of all academic physicists. I designed an online questionnaire for this population, built on the framework used for the *Factors Affecting Science Communication* study (Royal Society 2006), which I shall mainly refer to as *Factors* from now on. My questionnaire includes demographic data collection designed for a higher education context, looking at the number of years a respondent has been in post, the type of role they hold and job security, as well as where their current funding comes from. This enables the analysis to include comparison of sub-groups within the data alongside the normal demographic splits such as age and gender. At the time of designing the study the most accurate description of this population was that provided by the January 2012 Statistical report from the Institute of Physics, *Academic Physics Staff in UK Higher Education Institutions* (IOP 2012), which identified that there were approximately 4200 eligible academics from institutions that hold physics-based research teams or teach physics at undergraduate level.

Questions regarding seniority, role, funding sources and attitudes to public engagement were kept in the same form as in *Factors* so as to allow direct comparison of results. Additional long answer questions regarding the implications and nature of public engagement and outreach were added. These questions had been tested in my early EdD studies, designed to enable the participants to give detailed answers and develop their thinking around outreach as they moved through each subsequent question. Finally, the questions relating to motivations and barriers to involvement were altered to move the focus to working with school-aged young people, and the instructions for each page constructed to help the participant notice this shift in focus. I consulted with the outreach officer networks at SEPnet and the Ogden Trust to make sure that the questions made sense and would provide useful data. The final questionnaire was made available to the outreach officer groups for comment before testing within the population.

Rather than reduce my available population by piloting as a separate activity, I released the questionnaire to a small sub-set of my available population, 10 people in total, to ensure that the questions were answerable and that my timings were accurate. I received 4 responses in the allotted time, all confirming the duration of the questionnaire and that it worked effectively. There were two suggested changes from these respondents. The

first was to add a question asking about the participant's association with university networks. This was simple to introduce as a drop-down list, and the responses for this pilot group were established through follow-up emails. The second suggestion recommended that I provide a list of options for the questions where I asked for participant gender. I chose not to introduce this; the free-text box had been selected explicitly to allow all participants to enter whatever term they choose to describe the gender they identify with. In the final survey data I received one note of thanks for this action by someone who preferred not to say what gender they identified with, but appreciated the fact that I had not limited their choices. Overall, these post-pilot changes were small enough that I was able to include these early responses in my final data and, through email correspondence with this group, ensured they were aware that I was doing so, and that they would not participate in the final, more widely distributed questionnaire.

The last significant change to the questionnaire came from a conversation at an Institute of Physics Schools Outreach Support Network (SOSN) meeting before I released the final questionnaire. Given the high number of PhD and undergraduate students who take part in outreach, delegates at this event felt that I would receive responses from these groups, even though they were not my original target population. On reflection, and in discussion with both my supervisor and a range of colleagues, it became apparent that whilst undergraduate students really were not in the population at which I was aiming, as they would most likely only be involved with delivering standardised or basic science content, I should build the postgraduate cohort into my study. In response I updated the question related to level of seniority to include PhD students as an option, and altered the wording of the introduction and invitation emails to allow them to feel included.

3.2.1.2 Data collection

The final questionnaire can be seen in appendix 1. It was built in *Bristol Online Surveys*, a system I have access to through both QMUL and the Institute of Education, designed to be used for research purposes. The system is secure, and flexible, allowing useful collection and presentation of data. This system also allows the questionnaire to be

branded, offering some indication of authenticity to the participant, and is accessible through mobile devices as well as desk or laptop computers.

The online questionnaire initially ran from 17 October to 17 December 2014. It was sent out to outreach officer networks through the Institute of Physics, SEPnet and the Ogden trust, emailed to Heads of Department of Physics twice, and repeatedly tweeted from my own @cprthorley account, where I had 340 followers at the beginning of the activity, which increased to 420 by the end. The tweets received a lot of interest, and were retweeted to a much wider audience by science educationalists, communicators and physicists. I attended a variety of events where I raised awareness of the questionnaire, such as the Ogden Trust Outreach Officers meeting, SEPnet Outreach Officers meeting and IOP SOSN group. As might be expected, the response rate slowed down over time, with peaks of interest each time I attended an event or sent out a tweet or email. This first run brought in 192 responses, much lower than I had hoped, and so the response deadline was extended to 9 February 2015. Despite additional emails, tweets, contact with the outreach officers and Heads of Department to announce this extension the extra dates only saw an additional 10 responses, and so the questionnaire was officially closed.

The responses were exported into Microsoft Excel spreadsheets using the Bristol Online Surveys 'coded responses' function, then subject to descriptive statistical techniques as outlined in chapter 4. The resulting data allows for comparisons of response by sub-group, and statistical emergence of themes.

After checking and cleaning the data I was left with 190 useable responses, with three coming from scientists who were not full time employed by a UK HEI or research institution. Reviewing their responses and affiliation it became apparent that they were sufficiently associated with UK infrastructure to make their results compatible with the rest of the data. This total number of responses represents about 5% of my initially estimated population. However, as noted in section 3.2.1.1, I also opened up the survey population to include PhD students, and updated numbers on both the academic staff and PhD students for the academic year 2013/14, much closer to the time of the questionnaire, have since been released by HESA (2016a, b). This identifies the total

population as being 8955, including 4265 PhD students and 4690 staff, bringing my return rate down to only 2%.

3.2.1.3 Data analysis

It might be hoped that even with this reduced rate of responses it should be possible to generalise about the population. However, a first inspection of the data quickly reveals that this is not the case. The responses to this questionnaire are thoughtful, and the respondents identify in the main part as being active in outreach and engagement activities. Only three of the respondents were significantly negative with respect to taking part in outreach activities. I am convinced that there is a missing chunk of population, those who do not feel strongly in either way, who have chosen to ignore this survey and so are not represented in the results.

Gender is also an issue. Whilst one respondent pointed out that gender should not matter, in gauging how accurate a picture of physics departments I am building gender does indeed matter, because of the well-known under-recruitment of women into physics (Smith Institute 2011). Based on the IOP data for departmental staff and students, the population of women I should be expecting is around 15%; in fact 29% of my participants identified as female, 62% as male and the remaining 9% chose not to respond or preferred not to say. Weighting the responses against career level would reduce the significance and accuracy of this data, as I would have to control for the gender split at each level. Accordingly, I have chosen neither to weight these responses nor to generalise. Instead I use the gender and seniority splits to look for characteristic responses in other questions.

Microsoft Excel 2010 was used for all statistical analysis. As previously discussed I do not like black-box systems; I prefer a transparent approach where I understand the calculation that is being carried out, and as such this more manual version of analysis suits both my experience and interests. Long answer questions were coded thematically and checked with a second coder, as is described in more detail in section 3.2.5.

3.2.2 Case studies

In section 3.2.1 I noted the importance of carefully structured long-answer questions in the survey element of this study; acknowledging the disparate understandings of the terminology in this area (Facer et al. 2012, Wellcome Trust 2012b, Illingworth et al. 2015), these questions were designed to help the participant to explore their understanding of engagement and outreach as they moved from question to question. It is this inherent lack of shared understanding that drives the inclusion of interviews and observations in this study. Interviews are common in other studies; the *Factors* study used a series of follow-up interviews with survey participants to facilitate further insight into their questionnaire responses, and other studies, such as that by Ecklund and her team (Ecklund et al. 2012, Johnson et al. 2014), use semi-structured interviews from the outset, highlighting some of the limitations of questionnaires in seeking the perceptions of their participants.

Based on this concern and my engaged and reflexive stance I have included in the design of this study a series of nine case studies involving a total of eleven physicists, as summarised in table 3.1. Each of these case studies is based on the observation of physicists participating in outreach and on interviews with these physicists post-outreach activity. Such an approach is novel; whilst many of the studies outlined above include interviews in their fundamental approach, none have related this directly to participation in an observed outreach activity. The table lists the participants by chronological order of the observation taking place, with all names of people and institutions replaced so as to allow anonymity for the participants. The replacement names chosen indicate the participants' nationality and gender, or in the case of the institutions, their marketing and brand.

All of the case study data, from both observations and interviews, were reviewed using thematic analysis to seek the emerging themes of particular importance to the physicists, a process which is described in detail in section 3.2.5. In sections 3.2.3 and 3.2.4 I outline the concepts and processes for the observations and interviews before looking more closely at the process of thematic analysis.

Observation	Interview	Physicist	Career level	Institution	Activity	Location	Arranged by	Audience
1	Straight after	Alice	Post-doc	Cathedral University	Introductory lecture for schools experiment competition	Local 6th form college, staff meeting rooms	Outreach team	BTEC Applied Science lunchtime club
2	Straight after Straight after	Jonas Bill	Post-doc Head of Department	Coastal University	Introductory Cosmology lecture for Cosmology masterclass Contemporary research lecture for Cosmology masterclass	University rooms, not physics department	Outreach Officer	Mixed AS and A-level Physics
3	Skype 3 weeks	Wil	Outreach Officer	Historic University	Christmas Lecture	University main lecture theatre	Outreach Officer	Public, GCSE
4	Straight after	Rob	PhD student	City University & Voluntary Aided School	Mobile Planetarium	School hall	Outreach Officer & teacher	Year 9 and year 10 groups
5	Straight after	Vicente	Lecturer	Campus University	Contemporary research lecture for Schools Lab day	Physics department seminar room	Outreach Officer	AS Physics joined by year 10
6	Skype 5 weeks Straight after	Armin Marina	PhD student Lecturer	Industrial University	Contemporary research lecture for Medical Physics Masterclass Fundamental physics lecture for Medical Physics Masterclass	Physics department seminar room Physics department teaching lab	Outreach Officer	BTEC Applied Science
7	Skype 4 months later	Alexander	Professor	Industrial University	Contemporary research lecture for Stargazing evening	Outside, by the observatory	Outreach Officer	Public, primary school
8	Skype 3 months later	Mike	Ex Head of Department	Cathedral University & Grammar School	Chaos Theory play workshop	Science classroom	Teacher	AS and A-level optional session
9	4 weeks later	Jonathan	Professor	Urban University	History of Science lecture for public lecture series	Physics department lecture theatre	Physicist	Public, AS and A-level

Table 3.1: Overview of the case study participants and locations. All names and institutions have been replaced in order to avoid the respondents being identified

3.2.3 Observations

To my knowledge this is the first study of its kind to include activity observations; as such the design of this element has been informed by texts on the fundamentals of social science (Robson 2011, Silverman 2011) and literature related to higher education teaching and practice-sharing (for example Arthur 2009, Chamberlain et al. 2011). Accordingly, I planned to carry out eight observations to enable me to observe a variety of different activities on different sites, and for the physicists participating to be from a range of career stages and research areas; in the end I saw nine activities, as I will explain later on. The observations were carried out in person over a period of six months, on location at the site of each outreach activity, as summarised in table 3.1. These observations were primarily arranged through outreach officers; although I did also contact some physicists directly as a response to their positive response at the end of the survey questionnaire none of these contacts were able to provide access to an outreach activity on a suitable timescale for the study. The physicists and schools I did arrange observations through directly were contacts I had made through work, but that I had no particularly special relationship to. As I will go on to discuss in section 3.2.6, each physicist consented to my attendance at the event and a post-outreach interview. Whilst the physicists involved in these observations and the interviews may have completed the online-survey, it was not a pre-requisite of their inclusion in these case studies, and unless they gave their contact details voluntarily in the survey, I cannot tell if they completed it or not.

3.2.3.1 Data collection

Each observation took between one and three hours. The observed activities took place predominantly on university campuses, with a couple in schools. The practicalities of joining an activity influenced this element more than had I expected; to achieve these nine observations I arranged a total of twelve observations through liaison with individual physicists, outreach officers and schools. Despite the best efforts of all involved four of these did not go ahead, and one was added in at the last moment. The sessions that were most reliable were those run by outreach officers on university

campuses. In the cases where I liaised with schools or physicists directly there were issues with activities being confirmed or cancelled at short notice, making it difficult for me to arrange the time away from work to attend the sessions. Where I was attending a session arranged by an outreach officer or school the physicists being observed were approached through my contact for the session in the first instance to ensure the physicist did not feel pressured into participating; further communication about consent and interviews was then directly between me and the physicist. In each instance I asked to observe an outreach activity, and explained my interest in schools outreach, but left it with the individuals involved to determine the activity I attended. The result is a range of outreach activities that all involve a physicist speaking directly to a group of people, often schools but not limited to school groups.

Observations 6 and 7 were both carried out at the same university on the same day, and observation 7 demonstrates some of the randomness of outreach activities. Having arranged with the outreach officer to attend the masterclass that day, I arrived to be presented with details of the evening session as well, and permission from the participating physicists to carry out my observation. This alone would have been enough to make me attend; as I will discuss in the ethics section later in this chapter, I have taken every measure to ensure that my research in no way damages the relationship between the officers and the physicists. My refusal to attend could have caused unnecessary tension in the officer-physicist relationship, or provided a reason for complaint. There were also benefits to my attending that session. In planning my observations I had experienced difficulty in finding an activity aimed at primary school children, a fact that is unremarkable given the discussion of performance indicators in chapter 3. This hitherto unplanned activity was a public event but marketed extensively at primary schools and families, providing me with an opportunistic way of including this audience.

I attended the activities as a spectator, moving around primarily with the audiences. Accordingly, I have defined the boundaries of the activities to be those times where the physicist was beginning to change their behaviour through the direct influence of the audience; for most this is the arrival or departure of the physicist to or from a given space, or the arrival or departure of the audience. For two of the events, at Coastal and Industrial Universities (observations 2 and 6), it can be seen that there were two

physicists involved in each event, each with their own distinct contributions to a wider programme of activities for a given audience. In these cases I followed the audience from activity to activity, and was able to see a wider range of participating physicists because of this.

3.2.3.2 Ethnographic field notes

Field notes were written by hand *in situ*, without an observation schedule: an example is given in appendix 2. These notes included descriptions of the activity from the observer perspective as well as *verbatim* quotes from the physicists, and occasionally the audience at the events, in order to capture the actions and interactions of outreach delivery. In making descriptive notes I focussed primarily on the actions of the physicist, including their body language, movement and location, looking for aspects of the activity delivery that I felt were influenced by the physicists' understandings of outreach. I also looked for evidence of the work that had been put in pre-activity, and indicators that their delivery was being altered on-the-go by their interactions with the audience and location. To enable a clear distinction between the descriptive and verbatim records of the event and my own interpretations of the situation around me, I made two separate columns of notes, and typed these up myself as soon as possible after the observation, as shown in figure 3.3. Verbatim entries were marked with quotation marks, and each is marked with an indicator of who is speaking. The numbering on the left marks individual sections of the notes, which I used later to facilitate analysis.

	Observations	Reflection
14	She introduces the talk, and the details of a competition	
15	As she starts talking she's pacing backwards and forwards, speaking very fast, and even out of breath. This section is all about the competition.	I feel like shes not sure of the details of the competition (later confirmed)
16	Her pace slows after a few minutes, as the content is changing. This is her science now, the research she does directly.	She's happier delivering her research/science than the overall context
17	using props and diagrams, increase in technical information	some elements of her talk are black-boxed leaving some technical elements unexplained
18	Alice: "These light curtains measure by… …as you know"	Assumed knowledge, unlikely that a BTEC group would understand light use of light gates/curtains to measure speed.
19	Alice: "This is the science bit. We'll get through this and there are some awesome videos". She laughs.	She seems to be assuming that they won't find the technical elements interesting
20	Moves from descriing the light gas gun to how craters are produced on meteorites. Using lots of (beautiful) images of geological formations.	No connection between the two topics. I'm not sure why she's moved from one to the other.
21	Alice: "I forgot to say, I'm a geologist, working in a physics department". She's explaining more of her terminology now.	She seems happier explaining geology processes.
22	Students are still very well behaved, most seem attentive. A couple are subdued, looking into their food.	
23	"That was a very quick explaination of that, but that's essentially catatrophic disruption."	Shes speeding through content, but aware of it.

Figure 3.3: Extract from observation field notes, showing the descriptive and verbatim notes on the left, and my comments on the right

These observations were unstructured, in that I noted anything of interest; as such there are times when my focus shifts to the audience, depending on the activity of the physicist at the time. Through all of this I was looking for indicators that would indicate how the physicist, or sometimes the audience, was feeling about not just the content and delivery of the activity, but also their interactions with the others in the room. These guiding principles have also underpinned the analysis of this set of data.

3.2.4 Interviews

Interview elements are included in this design to enable the physicists to reflect on their performance during the outreach activities I observed and begin to consider how this fits into their wider contexts. Accordingly, each activity observation was followed by an audio-recorded, semi-structured interview with the physicist taking part in the outreach activity. The interview schedule can be seen in appendix 3.

3.2.4.1 Data collection

Interviews were carried out in a one-to-one environment as quickly after the outreach activity as could be arranged. Most were undertaken within a couple of hours of the outreach activity I observed, and took place in the participants' own offices. Some were more difficult to arrange, primarily those following outreach activities that took place in the evening, and so these interviews took place through Skype up to four months after the event I attended.

The interviews lasted up to 30 minutes, but were most commonly around 20 minutes long. All were recorded using the Voice Memo function of my iPhone, and backed up on iCloud, before being transferred to both an encrypted storage device and onto my IOE server, after which the iPhone and iCloud versions were deleted. This use of the iPhone was deliberate; aside from being a convenient tool to use, by being a commonly used device the iPhone is less intrusive to the interview environment than a dedicated recording device. The audio-recordings were transcribed using a professional transcription service, which I then reviewed and amended for accuracy before moving onto the coding stage. A sample transcript is given in appendix 4.

3.2.4.2 Conversations

The interviews are based on a semi-structured approach with a flexible schedule. I have elsewhere referred to this process as 'conversations'; whilst it is not traditional to use this term to describe the interview process, it is the term that I think most closely reflects the interactions that take place during the interviews I present as part of this study. In previous work (Thorley 2014) I found that in order to facilitate detailed responses it was necessary to be flexible with the interview schedule, moving questions around to flow more smoothly from the interviewee's most recent response. This is the approach I took for this study, allowing each participant to relate their answers back to their own context, experience and motivations. Additional prompts are then needed in places to help the participant stay focussed on the issues I am interested in. In places it has been necessary for me to contribute; for example to directly answer a question they have posed for me. In each case I tried to give answers that are factually accurate

without influencing their subsequent responses unduly. However, as I have noted previously, through my professional activity I have an existing relationship of some kind with each of these participants, even if this is just through reputation, and this adds to the interview process; as such, anything I have added orally is unlikely to have been more of an influence than my presence and the work and values I represent.

3.2.5 Thematic analysis, coding and reliability

I used thematic analysis (Braun and Clarke 2006) to underpin the analysis of all qualitative data: the long answer questions to the questionnaire, the observations and the interviews. Thematic analysis normally starts with the generation of a priori codes from the literature; however, I was concerned from my reading of the literature that certain assumptions are typically made about physicists taking part in outreach. One example is the common focus on time pressures as a barrier to participation in outreach. Whilst this would be an obvious a priori code, I am seeking to establish my own interpretation of any such barriers to participation in outreach, and do not wish to make such assumptions. To this end I have omitted the generation of a priori codes, drawing on a more grounded theory approach (Robson 2011, Silverman 2011). The approach I used is outlined in table 3.2.

Stage of analysis	Description
Familiarisation	Interviews are transcribed, read, and re-read. Initial thoughts are noted.
Induction	Initial codes are generated based on a thorough review of the data set.
Thematic review 1	Review of the induced codes is used to generate themes and identify associated data. First coding sheet is produced.
Application 1	Codes are reviewed through application to the full data set. New codes are created; others are discarded.

Thematic review 2	Review of the codes is used to create a thematic overview of the data. Codes are collapsed to meet the needs of the overview and ensure consistent coding.
Reliability	Collapsed codes are applied to a sub-set of data by second coder for reliability check.
Final coding	Final codes are applied to the data.
Analysis	Thematic overview of the data is confirmed; examples chosen from the data to highlight the issues raised and respond to the research questions; analysis carried out, referring back to literature and research questions

Table 3.2: The process of grounded-theory informed thematic analysis used to analyse the qualitative elements of data for this study

To implement this process I familiarised myself with, and then manually coded, all data following the steps outlined in table 3.2. The final coding sheets for the questionnaire long-answer questions, the observations and the interviews can be seen in appendices 5, 6 and 7 respectively. This process worked well for the questionnaire and observation data, but failed at first for the interviews. In this case once the full analysis had been undertaken I found myself dissatisfied with the outcomes, which presented the data under the same sorts of themes of time-pressures and lack of reward which are apparent in other literature, in fact those I had been trying to avoid as assumptions in my data. Such themes are important, and the final discussion in chapter 7 will come back to these issues and their place in managing outreach programmes, but to avoid making assumptions about their role in the physicists' perceptions of outreach I took a step back and some time away from the data to rethink my approach. The conclusion of this was to re-introduce a priori codes, but this time informed by my previous analysis of the observation data and using the codes that had emerged from this data as a starting point. By leaning on the outreach activity itself as guidance, I was able to generate a new set of codes for the interview data, ones that I would argue give deeper insight into the physicists' perceptions of outreach. Examples of samples under both coding schemes are given in table 3.3.

Sample	First coding	Second coding
No, it is not a priority. That is an important statement. I do it but it is not a priority. So the practical thing is that any academic has got to balance many calls on their time; so the priorities like this go as following: there is research, there is teaching, and then I will put outreach and then I will put administration last. (Jonathan)	Barriers to involvement	Factors affecting physicist involvement
Do I think there is a difference between school…? Other than the age range, I think there is. I think that the fact that your school is organising something, you might be rebellious to it. You don't like it, you don't want to do it. Again, it's the choosing part that, if it's public, the student will choose to go there. It's public. As I said, other than the age range, I don't see any difference. (Armin)	Definitions of outreach	What the audience is looking for

Table 3.3: Examples of interview samples from my first attempt at coding the responses, and the final revised codes based on the observations data

Such a review process is part of the process of ensuring reliability in the results. Based on my research approach the issue of reliability, and subsequently trust, is high priority to me. I need my results to be transparent and reliable if the stakeholders I wish to address with it are to engage fully with my findings and place their trust in my final results. However, much of the analysis relies on my work experience and knowledge, meaning that the way in which I interpret some elements is unique, making traditional reliability checks difficult. Where the data are less subjective I have employed the assistance of a second coder to help verify my interpretations of the data, following the process outlined in table 3.4.

Reliability check	Description
1. Data preparation	Data have been transcribed, coded, reviewed and coded again.
2. Indices chosen	Inter-rater reliability indices chosen to suit the method, in this case percentage agreement and Cohen's kappa.
3. Coder training	Second coder is chosen, and takes part in one hour of coding training with the principal researcher. If significant differences in interpretation of the data emerge, discuss and review codes, then repeat.
4. Second coder	Collapsed codes are applied to a sub-set of no less than 10% of the total data, by second coder.
5. Indices reviewed	The two separate sets of coded responses are compared, and reviewed using reliability indices. If $\kappa \geq 0.8$ and agreement ≥80% then the interpretation is considered reliable. For scores of κ between 0.8 and 0.6, or agreement between 80% and 60%, the coding is reviewed with second coder and decisions made together as to the reliability of the interpretation. For $\kappa \leq 0.6$ or agreement ≤ 60%, the codes should be reviewed with the second coder, and coding and review process repeated from stage 3.

Table 3.4: Description of the inter-rater reliability testing process

This process works well for the questionnaire, which used questions tested with colleagues, and where the responses are given with limited interaction between the researcher, who in this case is me, and the respondents. I am fortunate that, through the networks of outreach professionals of which I am a part, I have connections to others who have held similar roles to me in their careers, and my research approach means that we have discussed my research approaches at length. As such, there was one such colleague available to me as the most appropriate second coder for this work, and the results of this process are seen in sections 4.3.1-4.3.3 where I discuss the findings of the long-answer questions in my questionnaire. For this study I have chosen Cohen's kappa (Cohen 1960) and percentage agreement to indicate the reliability of the coding, with results as indicated in table 3.5; Cohen's kappa highlights the likelihood that any agreements in our coding are by chance rather than intent. This review process proved important; for question 5 the second coder did not draw the same distinctions as I did between where a respondent was talking about things that motivate them as opposed to

pressures they are under. This is understandable; it may seem logical that if someone feels under pressure to do something, that they will then do it. We discussed the codes, and agreed together where responses might be referring to pressures as a driver for involvement, rather than as a commentary on external pressures, and then the sample was recoded. For question 6 the problem was less systematic, and the κ result indicated a larger probability of coincidental agreement. Again we discussed and reviewed, highlighting a difference in the way we interpreted the emphasis of a response, and together agreed changes to the final coding. The results of both the original and amended coding are given in table 3.5.

Such an approach is more difficult for the data from the observations and interviews. Through the inclusion of subjective experiences, these case studies enable depth of understanding (LeCompte and Goetz 1982), but by immersing myself in the outreach activities I created a new relationship with the physicists through this observation process. As such it is highly unlikely that a second coder would understand and interpret the data in the same way that I do. Even with the less subjective survey data, and a second coder whose experience is as closely matched to mine as is possible, there was more variation in our initial interpretations than I expected; to ask them to interpret the observation and interview data would add uncertainty rather than reduce it. It follows that a second coder has not been employed for the case study data. Instead, the rigour of my analysis process, my openness about my methods and data (Anfara Jr. et al. 2002), and my professional expertise in this area provide the best defence possible for this analysis.

Question	Percentage agreement	Cohen κ	Result
Q5: Scientists are being asked to engage more with the non-specialist public. What, if anything, does this mean to you?	53%	0.40	Review and recode
	71%	0.63	Confirmed

Q6: Scientists are in particular being asked to take part in outreach activities. What does the term outreach mean to you?	66%	0.37	Review and recode
	88%	0.75	Confirmed
Q7: Do you see a difference between the terms outreach and public engagement?	89%	0.84	Confirmed

Table 3.5: Summary of the results of inter-rater agreement tests for questionnaire long answer questions

3.2.6 Ethics

In practice this activity had relatively low risk regarding ethical issues, but I have taken every effort to be as considered in this respect as possible, and adhered to the guidance set out in the *British Educational Research Association Ethical Guidelines for Educational Research* (BERA 2011). Given the issues with power relations in higher education and the nature of outreach being an additional, and therefore not always rewarded, activity for most physicists my first concern is with ensuring the participants are not at risk of any negative repercussions from their involvement. I am also aware of the overload of surveys that are carried out in higher education at the moment, and the additional pressures this adds to a workforce with an already increasing administrative load. Finally, I have needed to consider my own professional reputation, and the physics community's opinions of me and my research.

As such, I have taken various steps to mitigate these concerns. All communications regarding this study have been sent through recognised channels using my official QMUL email address. By reaching out to the physicist population through their Heads of Department and outreach officers the physicists did not have to communicate with me directly unless they chose to through opting in in the questionnaire or by contacting me directly. The invitation to participate in the survey (appendix 8) was accompanied

by full details of the research project, details of the right to withdraw and the intentions for dissemination of the results, as given again at the beginning of the questionnaire (appendix 1) and in keeping with the BERA guidelines. Physicists taking part in the observations and interviews were asked to sign a consent form, also outlining the details of the study and use of data (appendix 9). Any schools taking part in the outreach activities were also asked to give appropriate consent (appendix 10), although when the activities were also open to the public such consent was not sought. All responses have been presented anonymously throughout this thesis, and this will continue for any future publications.

Having outlined the concepts and processes behind this study, I will go on in chapters 4, 5 and 6 to present and analyse the data, before bringing it all together in the final discussion (chapter 7).

Chapter 4: Physicists' perceptions of outreach survey

4.1 Introduction

Following in the footsteps of those who before me have sought to understand more about scientist participation in outreach and engagement activities, this chapter presents the findings of a census survey of UK physicists, using an online questionnaire (appendix 1) for data capture. The details of the methods of collection and analysis are given in section 3.2.1, but it is important to note here that this element has been heavily influenced by the *Factors* report (PSP 2006a, Royal Society 2006). In total 190 usable responses were received and analysed.

4.1.1 Contextual information

Both this study and *Factors* include questions to collect the demographic data normal to most surveys, but accompanied by questions tailored to gather HE-specific data about career level and research interests. As mentioned in section 3.2.1.3, of the 190 respondents 29% identified as female, 62% as male and the rest opted to return a blank box or indicate their refusal, or preference not to say. The respondents were split across a range of career seniority (Figure 4.1), with the most responses coming from PhD students. I had not expected to have such a high return rate from Professors, but the very low responses from support and managerial staff are to be expected.

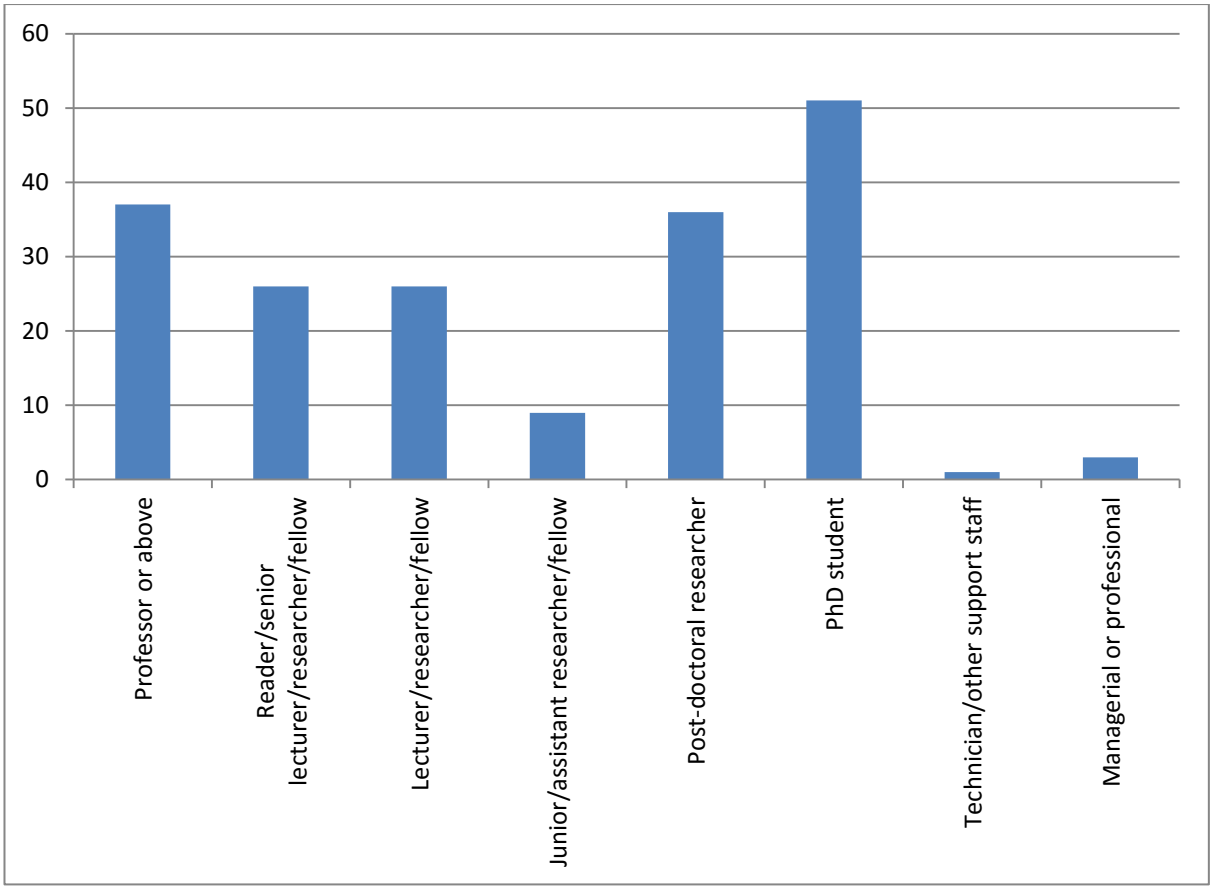

Figure 4.1: Breakdown of respondents by seniority

The majority of respondents indicated that they spoke English as their first language (78%) with the remainder spread across a variety of mostly European languages; German (3%), Italian (3%) and French (2.5%) were the most common. The respondents also identified primarily as White (88%), split across UK (61%), USA (4%), Mainland European (16%) and White-Other (7%). 4% identified as 'Other', including Slavic and Hispanic ethnicities but most did not give this additional information. Small numbers of Indian, Other Asian, Mixed Race, and Black respondents were also collected.

As might be gathered by the number of PhD and Post-Doc level respondents, my survey sample is relatively young, with 62% being under 40 years of age at the time of collection, 35% over 40, and the rest chose not to say. This is a very different population then to the *Factors* sample, who were for the main part over 40. It follows then that they have also worked in research for less time, 66% for less than 15 years and 33% for longer, again very different from the *Factors* data.

Finally, it is gratifying to report that 87 respondents (46%) indicated their on-going interest in the study, offering to be contacted again and to receive a summary of the research when completed. This supports my concern that the self-selected sample is already biased towards being interested in the topic of outreach, as discussed in section 3.2.1.3. Much of the literature in the area of web-based surveys seeks to improve response rates and avoid such selection bias through careful sampling or improved coverage (for example, Bethlehem 2010). However, given the concerns raised in chapter 2 around the additional workload that outreach represents to the physicists, it was essential for this study that participation be completely optional; I will discuss the implications of this for future studies in chapter 7.

4.2 Questions matching the 2006 *Factors Affecting Science Communication* Study

For most of this chapter I will concentrate on my own data, but for these first few questions I will also present some of the 2006 *Factors* (PSP 2006a) data to help set my own data in context.

4.2.1 The importance of different audiences

Figure 4.2 shows the mean participant responses to the question 'How important do you feel it is that you personally, in your current post, directly engage with each of the following groups about your research?'. The responses show that overall all the stated publics are valued to some extent. No set of responses was unanimous in considering a public very important or not important. Those publics with the most conflicted distributions of responses were the media, both print and journalists, who were valued very highly by some and much less so by others. Young people in school and outside of school, and teachers, are considered to be a very important public by most of the participants. This will set the context for any continuing analysis; as I previously established that my sample cannot be considered to be random, the likelihood is that people with particular interest in these groups are more likely to have responded.

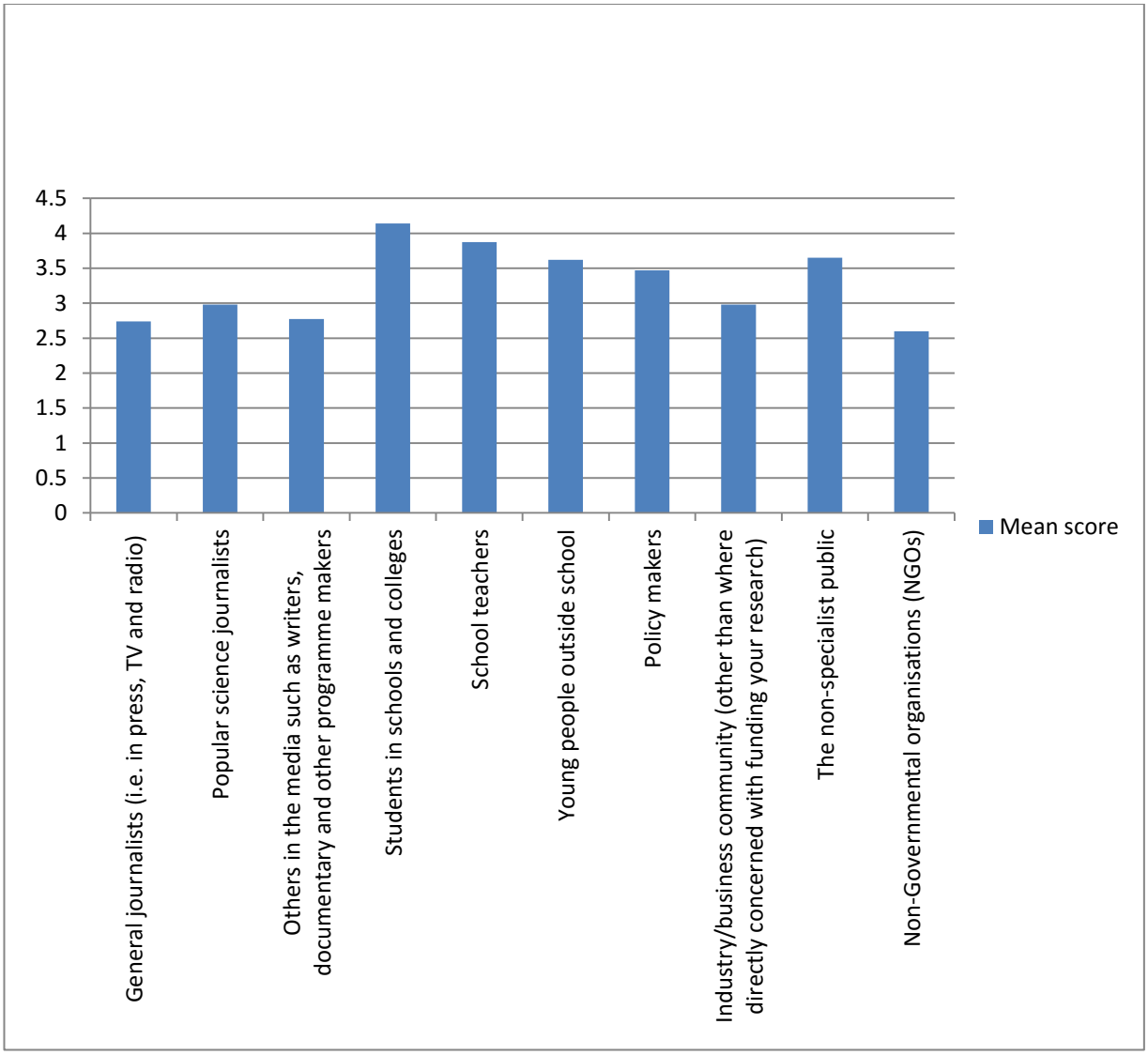

Figure 4.2: The relative importance of different audiences

The other questions can then only be considered in the light that this is, in the main part, a group who consider engaging at least one public to be important. Looking again at figure 4.2, outside of schools it can be seen that the respondents place about the same level of importance on engaging young people as they do to the general public and policy makers. It's worth noting at this point that the *Factors* study found policy makers to be the most significant public of interest with their combined 'schools and school teachers' category following. This may have been a response to the way the survey was delivered; it was an initiative run by policy-influencing groups.

The analysis for *Factors* suggested that female researchers might consider communication across all audiences to be less important than their male counterparts.

To check this within my data, the responses for each participant were summed across the ten categories and grouped. Minimum possible score per respondent was 10, indicating they had selected 'not very important' for all of their responses, and the maximum score was 50, indicating that they felt all the audiences were 'very important'. The responses are show in figure 4.3. 66% of participants awarded scores of 30 or more across the ten possible categories, reinforcing the argument that this population places high value on all types of communication and engagement work. The distribution of the responses for men and women is very similar, and so I conclude that there are no trends within my data that imply that women are more or less likely to consider this work important than men do.

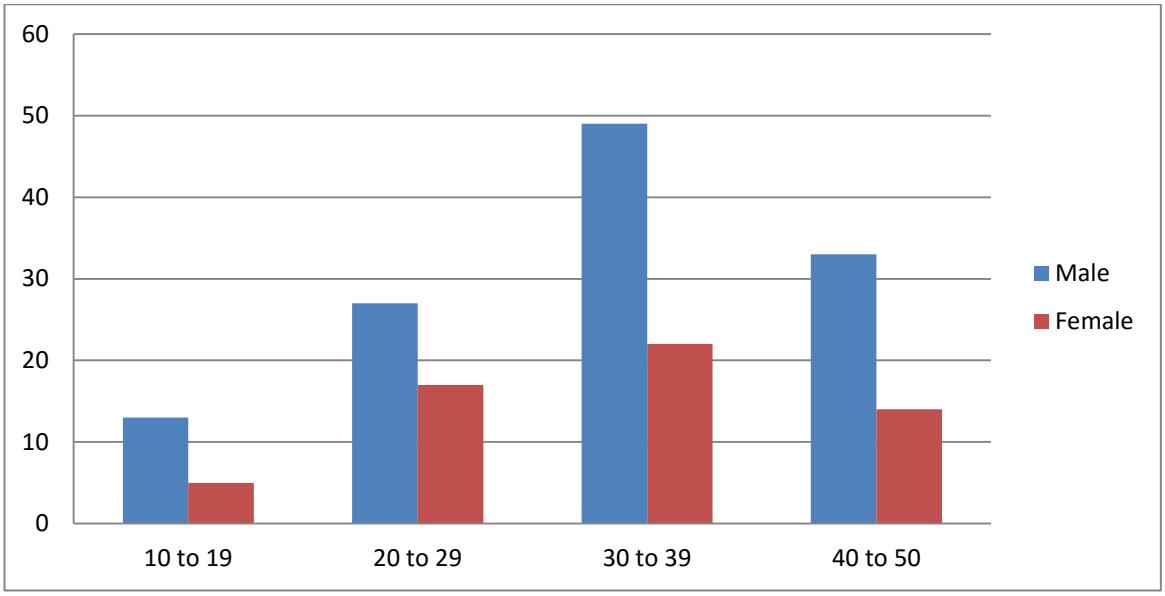

Figure 4.3: The summed responses across all categories for Q1

4.2.2 Difficulties in talking to different audiences

After asking the participants to consider the importance of specific audiences, both studies then went on to ask the participants to consider which audiences they find most difficult to talk to about their research. Again this question for my study was kept as close to the question posed in the *Factors* survey as possible to allow comparison, as shown in figure 4.4.

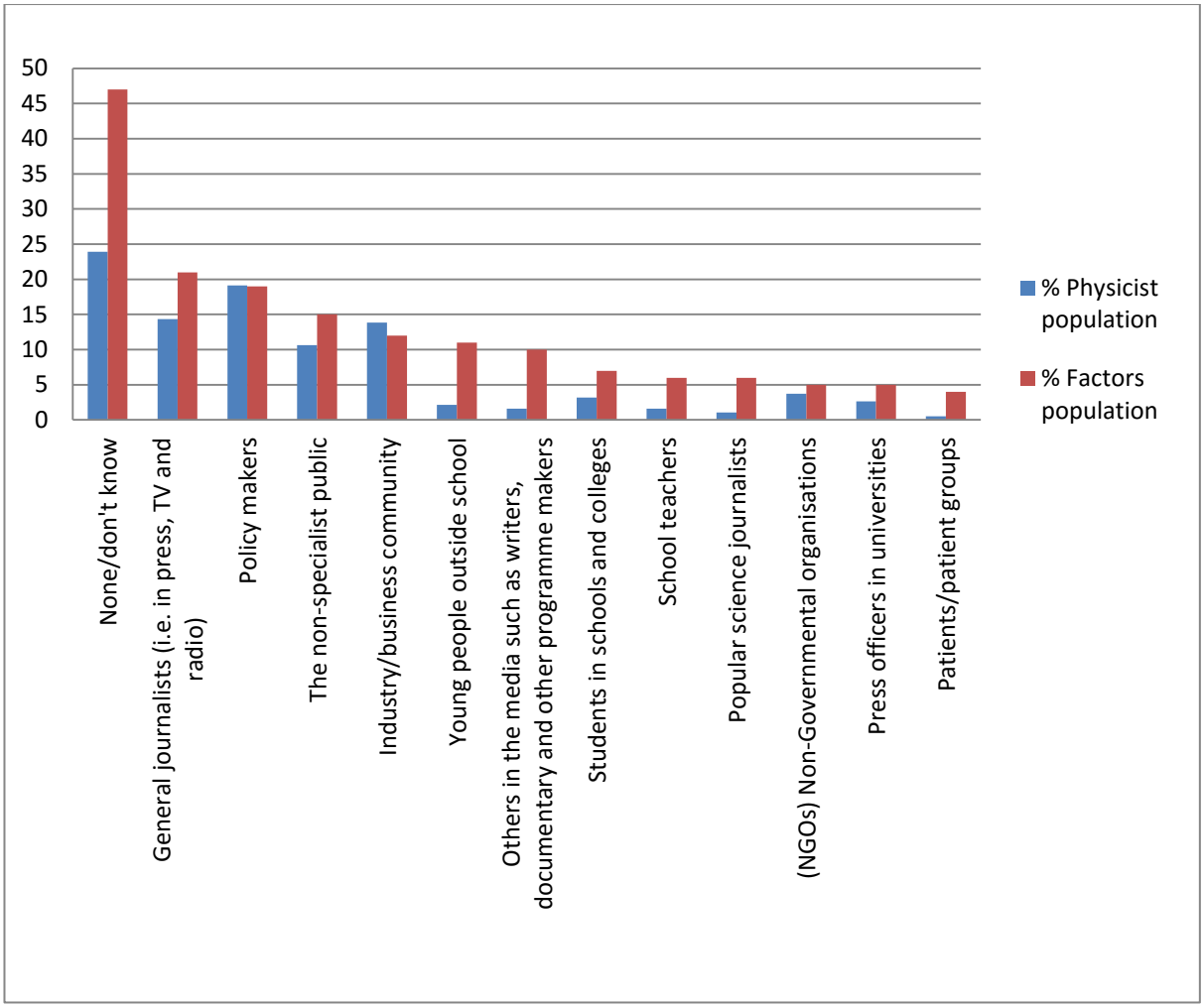

Figure 4.4: Responses to the question 'Which of these groups do you find it hardest to talk to about your research findings?' from the physicist population being studied, and the 2006 *Factors affecting Science Communication* study. Respondents indicated which public group they found most difficult to talk to through selection from a list

The *Factors* data show that more than one response must have been possible to their question, whereas my participants were limited to one response. As such, the responses cannot be directly compared, but I have presented them alongside each other to demonstrate the trends in the data rather than look at the numbers of responses alone. The information I am particularly interested in is related to schools and young people. The physicist population I am studying gave relatively few responses that identified young people or teachers as difficult to communicate with, reinforcing my conclusion that these participants are inclined towards communicating with young people. Within those responses that did indicate issues with this public, young people in schools and colleges were identified more often than those outside of school, or teachers.

Respondents were also given a chance to explain their answer here. Teachers are generally felt difficult to access, either logistically, “Do not know of any events to talk to teachers”, or intellectually, “I find, especially in primary schools, that many teachers are disengaged from science as a whole and are generally unwilling to be taught or to teach it”. School students present a different challenge, primarily around the need to simplify research findings. As one survey respondent put it:

> My research is quite obscure and I would expect students to be aware of only the most basic aspects (magnetism). Therefore, as the question is specifically about my research findings, the school-age group are probably the hardest to talk to. Generally however, if doing outreach activities I would target the outreach to be more relevant rather than try to explain why my results are interesting.

This sort of response to working with young people is to be expected. Later chapters will explore how outreach activities include elements of education and entertainment, and look at how content is derived from the well-established fundamentals of science as well as cutting-edge research.

4.2.3 Levels of activity

Having established the importance of engagement activities, both studies then go on to ask about how active in science engagement the respondents are themselves. Eleven categories of activity type were offered, and participants asked to indicate an approximate frequency for each category, the results of which are shown in figure 4.5. The notable absences in the categories here are TV work and citizen science projects, neither of which were included in *Factors* and so were also omitted from my study. The responses are presented as a percentages; it should be noted that the total number of responses for each category was not exactly the same as not all respondents answered. Total responses for each category ranged from 187 to 189.

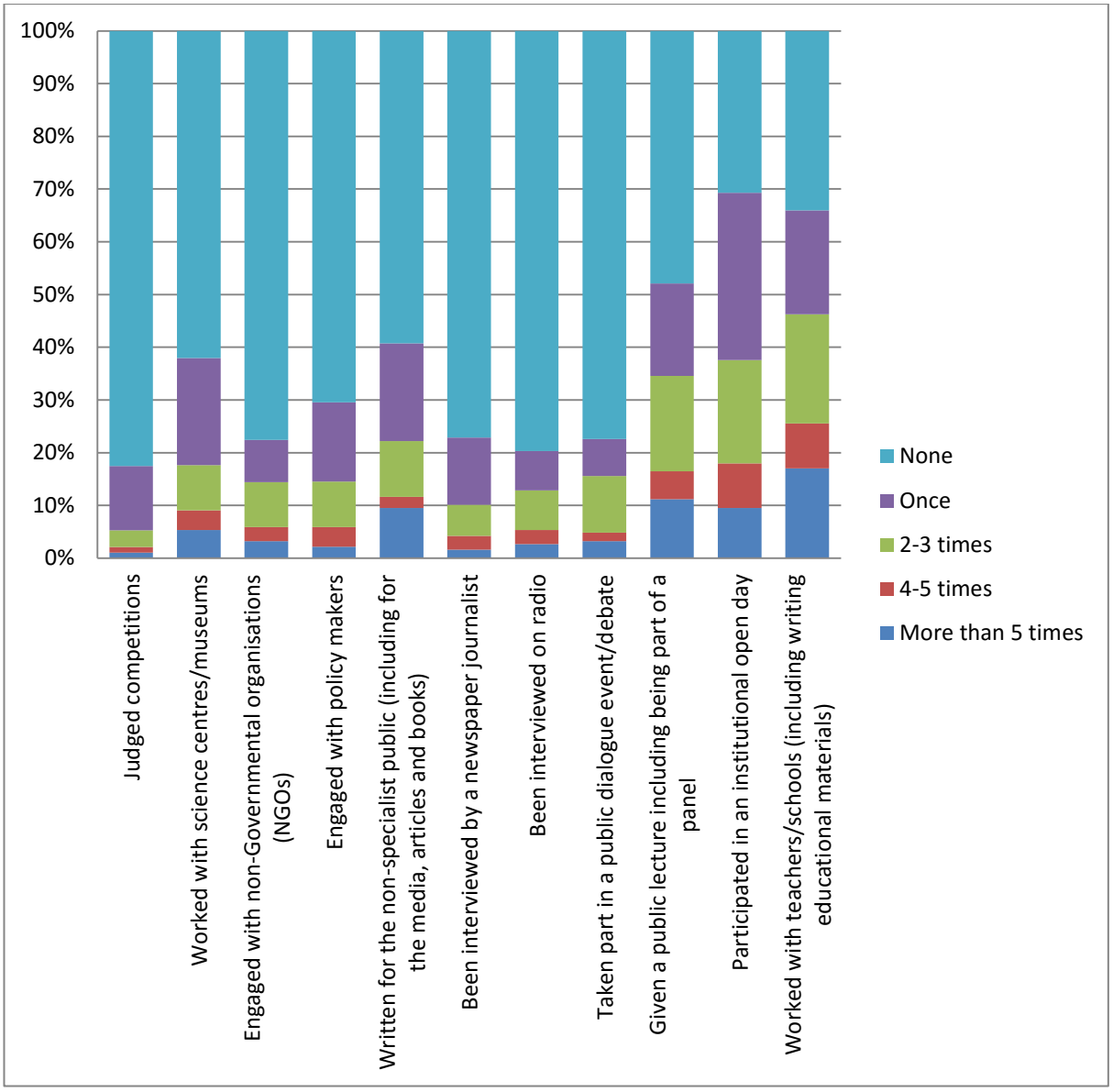

Figure 4.5: Respondent proportional activity levels for different science engagement activities

Institutional open days (69%), working with schools (66%) and giving public lectures (52%) are the activities that have been undertaken by the largest numbers of individuals, but working with schools is the activity that has most participants getting involved more than once. The *Factors* study also found open days to have the most participants, with 57% of their respondents indicating their involvement, followed by public lectures (40%) and working with policy makers (33%). Given the differences in the populations drawn upon for each study I cannot state with certainty what has caused the differences in the responses, but I remain conscious that my study was promoted with messages around engaging schools, and so I might expect a higher response to this category. The

Factors study included medical and environmental scientists in their population, with other disciplines that have significant policy and lobbying organisations associated with them, so it makes sense that that population would generate a higher interest in this particular public. Overall, the respondents to my study are more active across all the stated publics, and have a much higher rate of getting involved more than once with any particular activity.

Given my particular interest is in schools outreach, I took a closer look at the responses for the categories 'Worked with teachers/schools (including writing educational materials)' and 'Participated in an institutional open day', comparing the responses with information about seniority and gender. For the main part these responses showed no trends based on seniority or gender, apart from the case of open days. Respondents in roles with longer contracts or more seniority were more likely to have taken part in more than one open day, which makes sense when considering the annual nature of many such events, and their association with recruitment of undergraduates, a core driver for many departments. PhD students, and to some extent post-doctoral researchers, were less likely to have been involved at all, and had rarely taken part in more than one such event. Given that there is no such trend in the responses for the 'Working with teachers/schools' category, I conclude that this once more demonstrates the particular interest of my population in working with schools.

4.3 Long answer questions

To address some of my concerns around use of language and terminology I added some long answer questions to the questionnaire, each exploring aspects of outreach, schools outreach and public engagement. Questions 5, 6 and 7 followed on from each other sequentially to enable participants to develop their thinking as they moved through the questions. The responses to these questions have been coded as described in section 3.2.1.3, to enable comparison between them and those providing contextual information.

4.3.1 Implications of asking scientists to do more engagement activities

Question 5 asked respondents to consider the implications of being asked to engage more with the public, a question also asked in the *Factors* survey. The wording, 'Scientists are being asked to engage more with the non-specialist public. What, if anything, does this mean to you?', was kept as in *Factors* for easier comparison of results; however, this results in a wide variety of interpretations of the question, which was for some considered to be worded in such a way that the meaning was vague. Such breadth of responses is in itself an interesting finding, and many of the answers include an appreciation of the factors that influence the respondents' answers. Whilst many of the responses included definitions of engaging the public, most also included another key issue in their response. Accordingly, even though these were a significant element of the analysis from *Factors*, definitions like this have not been included here as a theme for analysis but are a focus of questions 6 and 7, discussed later in this chapter.

The majority of responses were positive in their outlook, some raising concerns or conditions for delivery such as one response 'Such engagement is important, but must be dialogue-based' where the support for engagement is explicit, but carried alongside an indication of what style of delivery would be best suited to ensure the best outcomes:

> I think that this is a positive step in opening a dialogue with the public. Hopefully such engagement will increase the knowledge level within the general public about research that is occuring and the importance that it has on day to day life. Especially in a world where scientific advancement is really key to solving many issues e.g. energy problems, food issues, transport solutions etc.

Some respondents acknowledged the tensions of their working environment, and the issues with engagement not being core to their workload, but still felt motivated to take part because of the opportunities to develop skills and the challenge engagement work presents:

> This is the highlight of my PE work: it is challenging and often uncomfortable, but immensely rewarding. However, this is not aligned purely with my research interests - indeed, it cannot be since PE surely means making oneself available to try to communicate science within an agenda/framework set by these members of the non-specialist public.

Given that my questionnaire was released very close to the time that the 2015 REF results would be announced I had expected to find more references to the impact agenda throughout the responses to this and the subsequent two questions. The awareness of the impact agenda was present, but not limited to 'Impact' as submitted to the REF. Notions of impact were tied to the visibility of the worth of research, and an inherent duty on the researchers to justify their public funding, yet also conflated with issues of continued funding:

> We need to show people that we are active and that Science is making progress. We also need to educate people and draw their attention to the challenges we face and shall eventually face. We need to seed the gains of passion for Science in youngsters for the next generation to arise. Eventually, we also need funding, policymakers need to be lobbied at some point, let's face it.

Some research areas associate engagement and outreach with impact more than others. This is more than just difficulties in developing other types of impact, such as commercial; where there is existing demand for engagement from the public, and so a more highly developed culture of engagement activity exists, it makes sense to capitalise on existing activity:

> I work in astrophysics, and one of the main justifications for research in this area, with limited (but non-zero!) commercial or industrial applications, is promoting general interest in science and technology. Astronomy and space science is in a very privileged position to do this because of the breadth of general interest, and the fascination of many children with 'space'.

Such public demand for engagement activities is not limited to astronomy, but is certainly not experienced by all of the respondents. In these cases the lack of perceived public interest in science can be in itself the most important justification for science engagement activity. For some there is a broad remit, for example 'Helping in some way to make science a bigger part of culture', but for others there is a perception of the public lacking not just in knowledge, 'Need to compensate for the failure of the school system to produce scientifically literate adults', but also interest, in line with the deficit model of science literacy:

> Asked by whom? By research councils perhaps, but there are very few opportunities for enganging with the public. The UK is quite a science-hostile country where scientists are not generally held in very high esteem but are generally viewed as a bunch of nerds in lab coats. Footballers and glamour

> models have a much higher standing in the public's mind. The only practically feasible way to change that is to work with children and let them experience how fascinating science is.

The perceptions the participants have of the public range widely. There are those who feel as the last respondent does and think the public are lacking in interest, and express themselves strongly such as one response, 'It stinks of having to justify good science to the ignorant!'. Most express a more complex view, not blaming the public for their lack of interest but acknowledging the culture they are within, and realising the limitations of their own experience and skills in being able to make a difference:

> While I feel this is important, and that as scientists we have a duty to explain our work (and rightly so, as the public fund much of it) I do think this is a bit of a one-way street. Aside from the school curriculum, there doesn't seem to be much encouragement for the public to understand science. On a number of occasions I have heard "Oh, it just goes over my head" and it is extremely frustrating to have to face this from a public that you are trying to explain (even justify) your work to. I also feel that training for public engagement is lacking and not promoted within institutes.

Having established this concern for scientific literacy in the public, it is heartening that there are a much larger number of responses that give positive views of the public, such as "This is really important as the general public are more interested than people think in what research is being done". Most responses acknowledge that different publics have different skill and interest levels:

> It means talking to anyone who is not a scientist about what I do, why it is important etc.. It means doing that in a way in which they can appreciate at least some of what I do, ie. getting the right level for the people you are speaking to.

As well as perceptions of the public, definitions are also offered. 'Non-specialist' as taken from the wording of the question is deliberately ambiguous, and some take it as the focus of their response:

> Personally any public is probably non-specialist in some form. Undergraduates which I teach are as non-specialist in the area that they are learning new as the audience at the University of the Third Age (and sometimes more so).

Many ways of identifying an audience are referred to, with the general public being the audience referred to the most. Despite acknowledging that to engage different audiences means changing style or content of delivery, none offer advice as how to target an

activity to a particular audience. This is a consideration I will come back to in later sections.

My own understanding of the question is that it is asking the respondent to consider the ramifications of a growing external agenda around engagement activity, and there were a significant number who also understood the question in this way. For some the implication was a need to increase activity, "That I should think about how to incorporate engagement into my current activities - that it is part of my job, essentially"; for others it indicated a need to reach new or wider audiences:

> Not sure what this question is asking, but to me this means going beyond people who already have an interest in science (e.g. in the case of my own area, talks to amateur astronomy societies, who probably count as specialist in terms of their interests if not necessarily their background knowledge in a particular area).

An anticipated implication from the literature is increased pressure on workload or time, which did emerge in the responses, but never alone. Where additional work was highlighted it was acknowledged that that work would at least be enjoyable, or is important. Recognition for this work, however, was considered to be missing for most:

> This is a great idea - we should do more of this. It is not however recognised as an important part of our workload.

> You can interpret this question in a couple of ways. In one sense what it means is 'more work with little real credit or kudos' and in another sense it means 'giving public lectures' which is generally fun.

For others, the increase in the external attention to engagement was seen as a way of improving the recognition they get for this work:

> I am very pleased that we now have a recognition of that and what I have been doing for the past 30 years is becoming a requirement. Colleagues in the past have been unwilling to take part because of the pressure to publish. James Clerk Maxwell himself gave lectures to 'working men'.

This last response indicates that the growing interest from policy and government bodies in public engagement activities has the potential to increase the number of researchers who are active, but only when balanced by acknowledgement of the concerns about recognition for such work.

This question asked about public engagement to match the question asked by the *Factors* survey, and also to provide an open question for the respondents to start considering their opinions about engagement and outreach activities. The following questions close in on this, asking participants to consider the specifics of outreach and engagement activities.

4.3.2 What does 'outreach' mean

When designing this question I assumed that the responses would be complex but limited to the usual discourses around outreach, such as recruitment and targets, modes of delivery or motivations for getting involved, as discussed in the literature review. I had hoped to be able to identify common themes, to enable better shared understanding between outreach officers or managers and the researchers involved. Accordingly, I expected the population to return very structured answers, limited to simple concepts. In reality, outreach is a term used in a highly complex environment and the answers proved to be much more complex; indeed, most answers could be coded in a variety of ways. Motive, methods of delivery, concepts of engagement and desired outcomes are overlaid in intricate and sometimes conflicting ways. In coding responses to this question I have aimed to identify the prompt the respondent has used to kick-start their thoughts, and then use the other topics they highlight to add detail to the emerging themes. This complexity meant I was concerned that there would be significant difference between how the second coder and I approach the responses, so I approached her early on with the coding schedule for discussion. The result is a very simple set of codes for this question, as seen in appendix 5; Did they see a difference between engagement and outreach, did they argue that the terms were interchangeable, or were they genuinely uncertain as how to answer? This approach enabled a high correlation in our coding, as seen in section 3.2.5.

Over half of the responses were underpinned by discussion of the ways in which researchers interact with various publics. A subset of these included attempts at providing a definition, such as 'Taking your skills to the outside world, i.e. to schools and public events.', or 'bringing popularized yet scientifically exact knowledge to non-scientists and stimulate their interest in the Science'. These definitions include a sense

of movement and direction, using words such as taking, bringing and giving to indicate transfer of knowledge and ideas between the researcher and the public. Taking this a step further, several responses included notions of help:

> Outreach is a way of helping others. Whether this means helping other to understand science, or just spreading about positive messages about education the goal is to help others.

The idea that outreach is beneficial to the target public is implicit in almost all of the responses. There are some exceptions. A second grouping of responses considers issues of recruitment and formal advice giving as part of outreach activities, including advice about careers. Within these responses the motives for outreach are critiqued, and criticised:

> [Outreach] reflects the desparate attempt to lure young people into a career path which is considered beneficial by the policy makers.
>
> Taking science outside the university/lab and into public spaces. Not the same as student recruitment.

Both of these views express the awareness of external drivers on the nature of outreach programmes, and acknowledge a tension that is often felt in departments. As noted in the analysis of the responses to the previous question, outreach for many is considered something they do because they enjoy it; by adding targets and external agendas it is possible not just to damp this enthusiasm but also to diminish the apparent value of the activity. The particular tension with student recruitment is particularly problematic for those working in schools outreach. However, there are those who respond well to these targets, and I will come back to this discussion in later chapters.

Given the theme of outreach as a way of helping people it is not surprising that attitudes to recruitment are mostly negative, in that it is self-serving or profit-making rather than philanthropic. However, recruitment is one of few tangible outcomes offered by respondents, for example as a result of outreach as a form of education:

> An outreach event is any event where you attempt to educate others on a particular subject for the purpose of either recruitment or developing a favorable opinion.

Developing positive attitudes and increased motivation for science recurs as an aim when defining outreach as explaining science to the public, and is commonly mentioned alongside education, for example;

> explaining science to the wider public – not necessarily just my research, but science in general, with the aim of making the general public more scientifically literate, so they can form properly informed on issues such as climate change and vaccinations etc.

The largest number of responses offered the idea that outreach is transmissive in nature:

> A one-directional communication of ideas, inherently associated with the deficit model of science communication.

Very few responses were as clear cut in their identification of a style of communication, and most returned to the theme of public good:

> Outreach seems to imply communicating ideas in a way that improves the other person's life or does some sort of public good, such as encouraging more people to go into science or helping people from deprived backgrounds.

Whilst the majority of responses were led by modes of interaction, many were structured around the target public. Unsurprisingly, given my research questions, a number of these related to schools work:

> Sadly for me, outreach means “schools”. This is unfortunate as at one level I can see that the term is much broader (see answer to question 5) however generally when my colleagues or I talk about “outreach” it is in terms of going into schools.

The sense that the meaning could be broader but is for various reasons constrained was manifest in several responses:

> Outreach is reaching out to engage people in science. I often use it as shorthand for schools outreach, or engaging with children in educational settings.

> Outreach to me means communicating with non-scientists in particular school children and teachers. Nevertheless, the public as a whole should be involved.

This feeling that outreach should not be limited to schools is borne out by those who clearly identify it as an activity for a wider public. However, 27% of the responses mentioned schools or children in some way, and the majority of these were supportive

of the idea that outreach is a term used to mean working with schools, although importantly this is normally as part of a wider definition of activities for the public:

> To take part in science related activities in schools or at community events. Also including in-reach- schools come to campus for activities

> Outreach means writing articles and given presentations aimed at the general public, in particular at schools.

Whilst this represents a significant interest in schools and youth audiences, they are by no means the primary target. Only 9% of the total responses identified outreach as an activity to be targeted only at schools and young people, and half of these again focussed solely on schools.

Finally, there were those who had never really considered the definition, and went away to look it up:

> I have always used "outreach" and "public engagement" as if they were synonyms, but realise that this is not strictly correct. On the other hand, Wikipedia also assumes that the two types of activity are equivalent: http://en.wikipedia.org/wiki/Science_outreach

This particular issue is addressed again in the responses to question 7 where all respondents consider the difference between outreach and public engagement, but I think it is worthy of note here because of the reference to Wikipedia. There is no one common portal for definitions of outreach and engagement. Whilst institutions/structures such as the National Coordinating Centre for Public Engagement and IOP SOSN do exist, they are not accessed widely beyond the network of engagement or outreach professionals who have made it their work to engage with them. As I referenced in the literature review, some time ago there were guidelines through national STEM initiatives, and a definition of outreach was available on the BIS website. The removal of these pages means that without specialist knowledge of outreach or public engagement networks it is difficult to develop a shared understanding of terms; as a result those interested will resort to secondary sources such as Wikipedia.

4.3.3 Do they see a difference between outreach and public engagement?

Finally, question 7 asked 'Do you see a difference between the terms outreach and public engagement?'. Rather than provide a menu of answers, this was left as a long answer box to allow respondents to discuss their answers if desired. I then coded each answer with Yes, No or 'Not sure' for those answers that were inconclusive. For this question there was an 89% match with the second coder. The responses can be split as follows in figure 4.6.

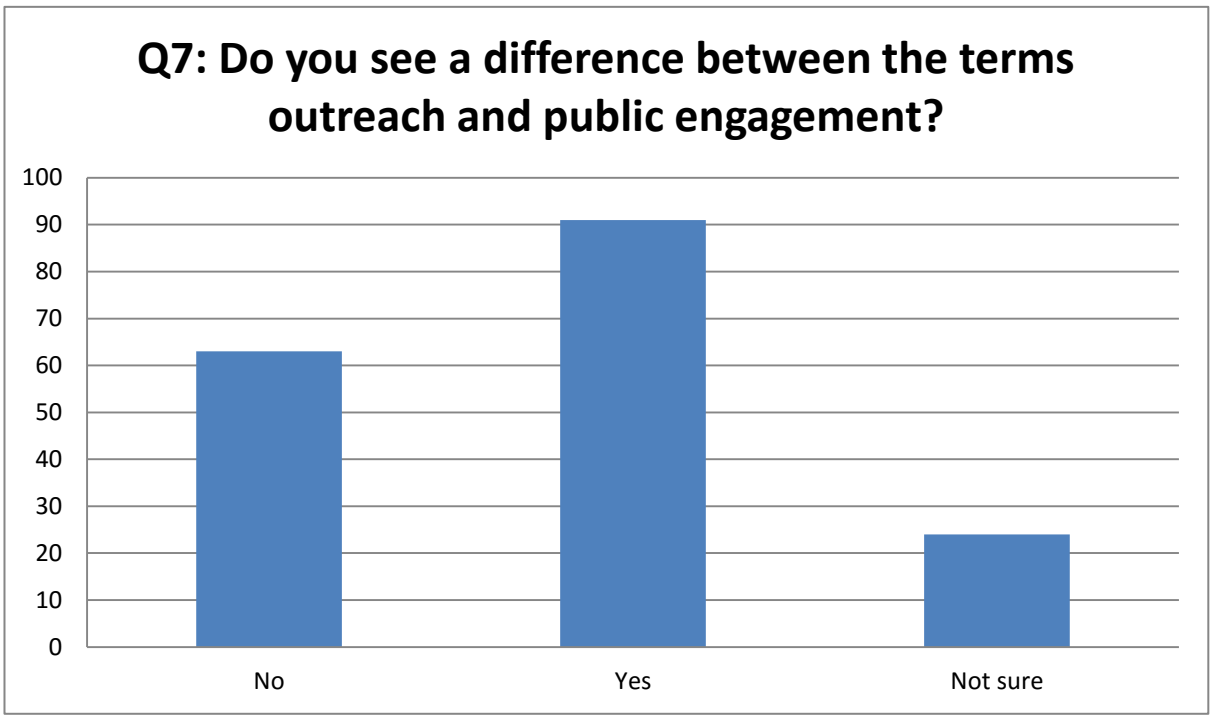

Figure 4.6: Results of coding the responses to question 7

Whilst reviewing the data for question 7 it became apparent that the perceived difference between outreach and public engagement was not as clear cut as I might have expected given my history of working in an outreach environment. Answers exploring the difference between outreach and public engagement varied widely with no conclusive trend, exploring issues of reach, breadth of content, breadth and variation of audience, variation in delivery mechanism, variation in motive and more. Much of this aligned to the codes used for the interpretation of the responses to question 5, but with irregularity of association and lack of distinction or definition in their descriptions of both outreach and public engagement. For some, outreach is anything where the public

passively receive the information being offered by the speaker, akin to the deficit model of science communication. This is often associated with other accountability or duties:

> Outreach implies more civic-minded goals (e.g. encouraging more people to go into science or helping people from deprived backgrounds) whereas public engagement might involve answering questions about research that come from the public, rather than pushing the scientific research onto them.

For others, outreach is workshop or practical science based:

> In my opinion, outreach is more hands on workshops in small groups, public engagement is larger scale events in large pubic places (town centres, NT properties etc) and public lectures.

As the previous response shows, public engagement definitions range from broad reach to tailored engagements depending on whether the respondent focuses more on the 'public' or 'engagement'. For those with a focus on 'public' breadth of audience, or access to events drives their answers as above. Where 'engagement' is more influential the discussion becomes harder to navigate but themes of dialogue or public feedback or participation come through:

> The difference should be in what you get in return. Outreach is usually interprets as a one way process in which the science is explained to the public but the scientist is not actively engaged in learn something in return. Public engagement is any activity in which both the parties (the scientist and the public) are getting something in return. It is true though that nowadays outreach and public engagement are assuming the same meaning even though the concepts are in principle different.

But in all cases there were examples of responses that offered the opposite opinions:

> When addressing outreach it seems to me to imply a very specific goal like promote women in science ... public engagement feels more general.

> Where outreach is to help others, public engagement is involved with telling others about what you (the public engager) do. This goes on to help further your field by spreading interest and knowledge, rather than putting helping others first

This overall feeling of confusion in the usage of terminology was summarised somewhat tersely by one respondent:

> No. They are both meaningless terms used by the chattering classes.

However, responses related to schools and young people were the clearest given, potentially indicating that those active in this area are more confident in their understanding:

> Outreach makes me think more of schools and public engagement typically makes me think of a public lecture.
>
> I do use the two terms interchangeably but if I was to try and define a difference between them I would say 'public engagement' is a more limiting term, only referring to activities that are open to anyone whereas 'outreach' would also encompass visits to schools to provide practical classes or talks to pupils. Any 'outreach' should be 'engaging' so my only perceived difference between the two terms would be who the target audience is rather than the activity itself.

I reviewed the data again, this time looking for the triggers I had expected to find, marking those responses that talked about working with young people and schools, and those that mention outreach. Given the low rate of responses referring to schools work for the previous question, I expected that work with schools would be mentioned more often here as the respondent was pushed to consider the differences between outreach and public engagement. The results were surprising; despite the external and institutional pressures related to recruitment that are associated with outreach funding, and given that my survey was clearly defined to the respondents as looking at schools outreach, only 19 responses mentioned schools or young people at all. Of these, 15 identified outreach as working with schools. Only three of these were respondents who also identified outreach as working with schools in the previous question, so it was worth pushing the respondents to consider the two agendas in parallel, but even so these numbers are much lower that one might expect given the nature of my study. This raises a question for me about when the discourses I expect to hear around recruitment will begin to emerge more strongly, if at all, and so the following section concentrates on questions related directly to outreach to young people.

4.4 Looking more closely at outreach to young people

The remaining questions in my questionnaire were used to examine perceptions and activity in schools outreach activities specifically, moving away from earlier themes of

wider engagement. The questions mirrored, but did not match, questions from the *Factors* survey. The first of these looked the types of content a physicist might think would be important to include in an outreach activity, followed by a comparative question asking what content they consider most important to include when they themselves are delivering an outreach activity, responses to both of which are shown in figure 4.7.

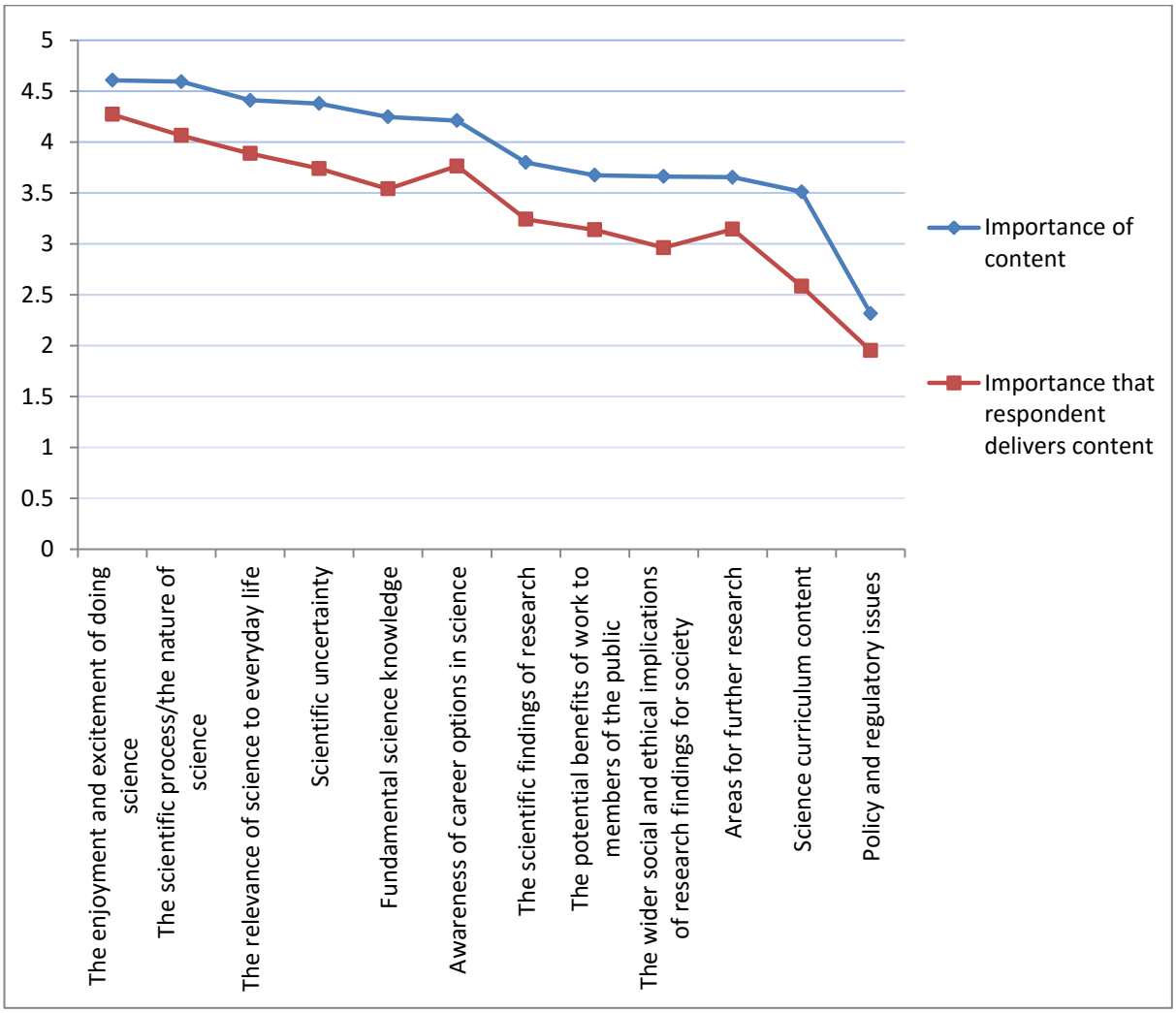

Figure 4.7: Responses to the questions 'Q8: How important do you think that it is that school-aged young people engage with each of the following?' and 'Q9: How important do you think it is that you personally, in your current post, engage directly with school-aged young people on each of the following?'. Answers were given on a scale of 1-5, where 1 is not important and 5 is very important. The mean scores are presented here, in descending order as given for question 8

As might be expected based on the motivations for public engagement outlined earlier in section 4.3.1, most importance was placed on conveying passion for science and the

scientific process. In both cases introducing the fundamentals of science was considered more important than relaying current research findings. While I had expected the respondents to consider it unimportant that they personally convey science curriculum content to the young people, it is interesting to note that whilst the respondents consider this to be somewhat important for the young people to engage with generally, this still comes very low in their list of priorities. Of particular note are the responses to the categories related to careers information and future research, where the responses indicate that the participants see these as being relatively important for them deliver personally. However, the overall trends of the data indicate that whilst the respondents think many of these topics are important for young people, they consider their own role in conveying these topics as less important, although the numbers are large enough to imply that their role is perceived as significant.

This is reinforced by the response to a later question, shown in figure 4.8. Engaging young people is seen as somewhat important to this group in relation to the other things they balance as part of their workload, although a significant number consider it not very important. This may be due to the question asking them to specifically consider the balance of their workload, whereas anecdotally I understand that much of this work is done in a researcher's spare time. I will return to this issue later on in this chapter when considering barriers to taking part in engagement activities.

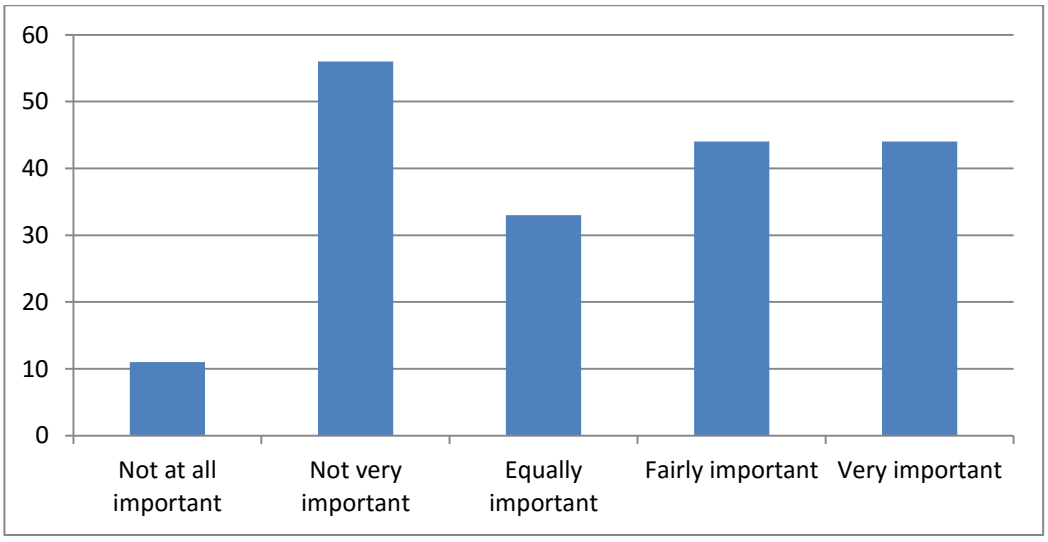

Figure 4.8: Responses to the question 'In relation to the other things you have to do in your working life, how important is it to you that you find time to engage with school-aged young people?'

These findings are supported by the respondent's considerations for the reasons why they might get involved with schools outreach. Figure 4.9 shows the most important and second most important reasons to get involved with such activity as selected by the respondents.

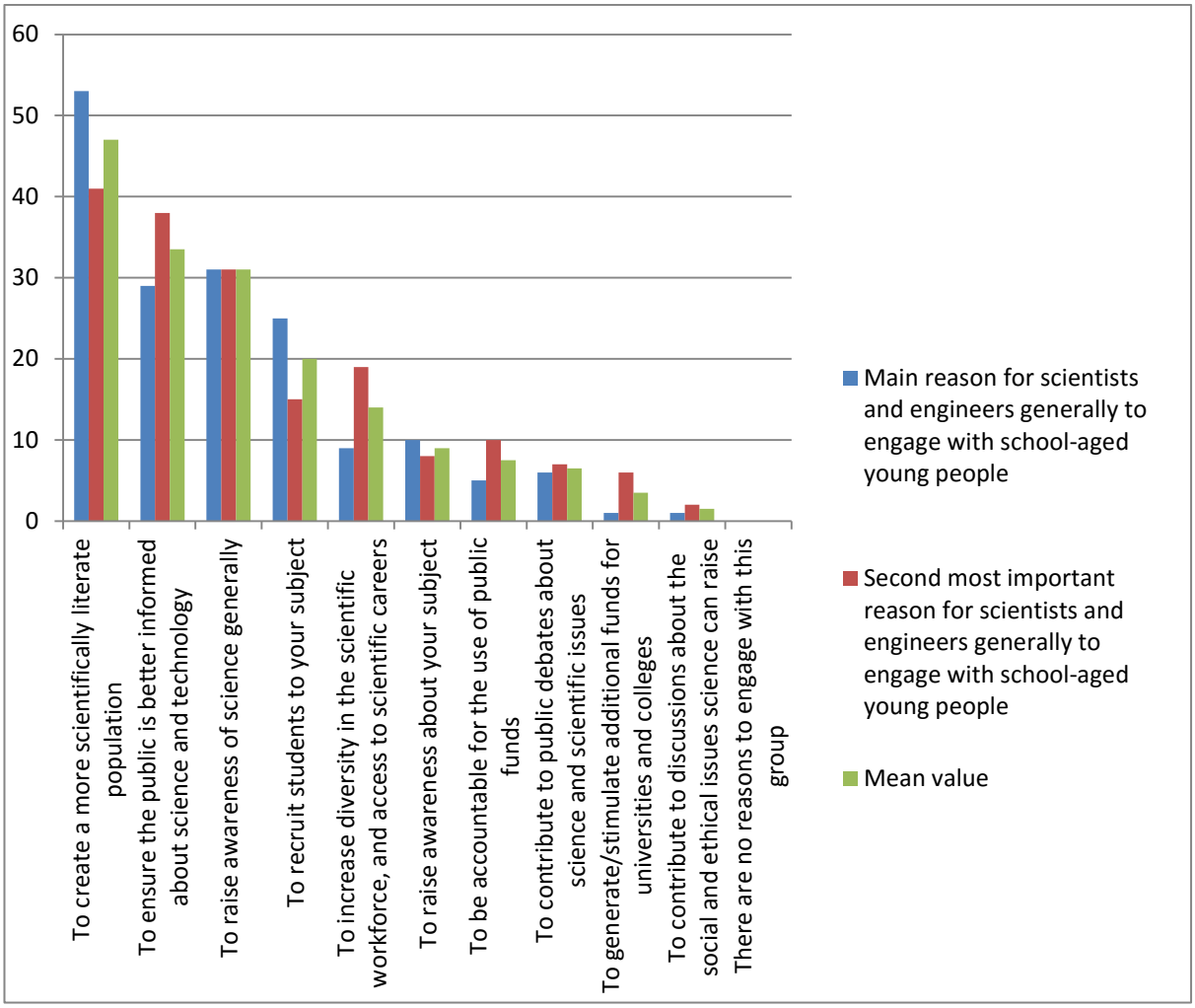

Figure 4.9: Responses to the question 'Looking at the list below, what do you think is the main reason for scientists and engineers generally to engage with school-aged young people?'. Respondents were then asked to indicate the second most important reason. Categories are ordered by the mean of these two scores

Here we see recruitment emerge more strongly than in the free answer questions, but still significantly less so than more philanthropic aims of improving scientific literacy, understanding and awareness. Accountability and duty of sharing knowledge had been strong discourses when considering wider public engagement, but are diminished now we are considering schools and young people only. There were no respondents who selected that there are no reasons to engage this particular public, but an 'other'

category was offered, where the majority of responses were different wordings of the offered categories and so their data could be reallocated.

4.4.1 Barriers to engagement

Having established in the literature review that scientists report various difficulties with engaging the public, but also having found that the respondents consider engaging this particular public to be important, it is interesting to consider what barriers, if any, they face when trying to take part in outreach activities. Figure 4.10 shows the respondents' considerations of what drawbacks there might be to getting involved with this particular public. There were 189 responses to the first question, 169 to the second; the figure below then indicates that the predominant feeling amongst my survey population is that there are no drawbacks to engaging with young people.

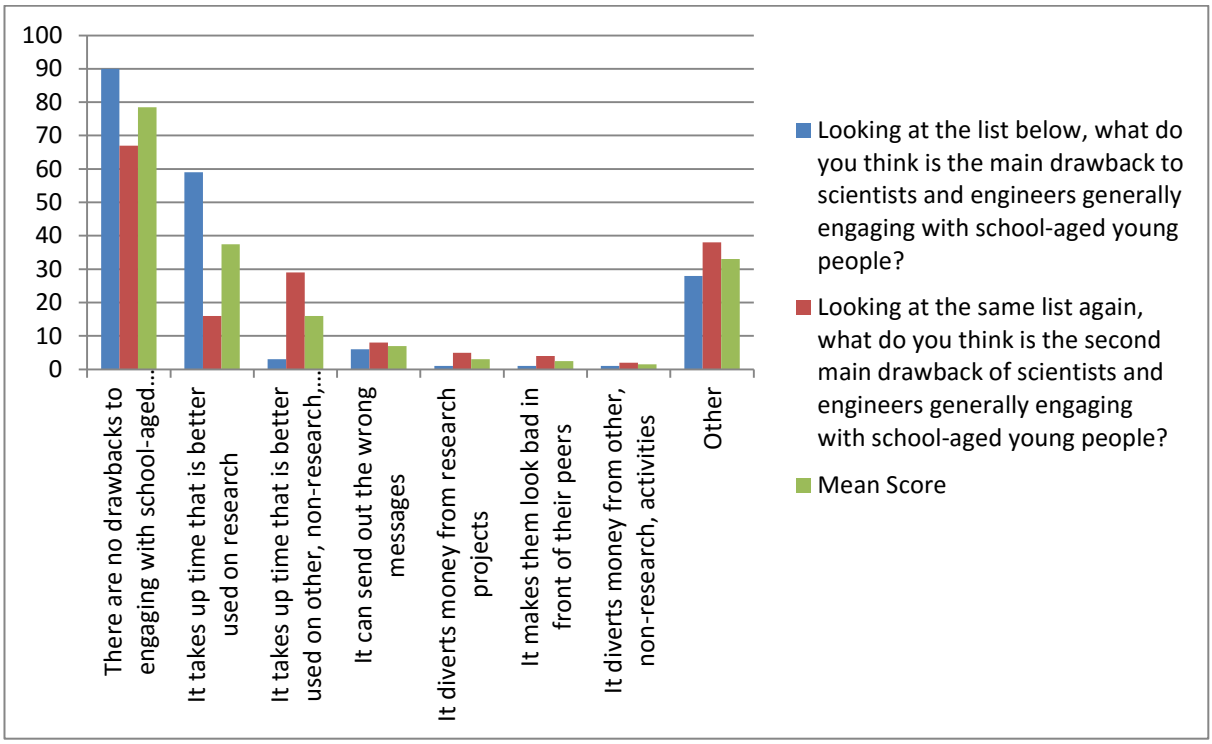

Figure 4.10: Responses to the question 'Looking at the list below, what do you think is the main drawback to scientists and engineers generally engaging with school-aged young people?'. Respondents were then asked to indicate the second most significant drawback. Categories are ordered by the mean of these two scores

It can be seen from figure 4.10 that the 'other' category was used by a significant number of respondents. Despite two of the offered categories asking about time pressures, the time outreach takes up was the most common response:

> It simply takes up time which we can not always find for this activity if we want a proper work-life balance.

As this particular response shows, by limiting time concerns to being in direct competition with academic workload such as research or teaching fails to recognise that this activity is often done in a researchers spare time, as I suggested when considering figure 4.8. For the physicists balancing a variety of different pulls on their time is complicated, for example 'It takes time and energy that the institution requires be used on other things.'. This notion that the institution would rather their energies be focussed elsewhere is also a common response, with the REF, publication and research income being valued more that outreach in appraisals, promotions and job application:

> I wouldn't say time is "better" used on research, but outreach is undervalued as part of a career. More papers will always beat a balance of papers and outreach.

Despite concerns from the literature, and anecdotally from colleagues working in outreach, that early career researchers and PhD students are the most vulnerable to these time and performativity constraints there was no indication that any seniority group felt these pressures more or less than others. There was also no reportable difference for different genders.

The third theme from the comments was concerns about quality of experience for both the scientist, for example 'it can be upsetting when you talk to groups that appear disengaged', and for the young people:

> There has to be a genuine enthusiasm for outreach/public engagement on the part of the scientist, otherwise it's counter-productive. Coercing academics into doing outreach simply to "tick the impact box" is not a good idea.

The issue of pushing scientists into an activity they might not be suited to came out strongly, with concerns being raised about the impact this might have on the students, for example "A poorly trained/unsuitable scientist can actually have a negative impact

on students", and this echoes concerns from the literature about the potential negative impacts of outreach.

Notwithstanding these concerns most of the respondents considered themselves to be reasonably well equipped to engage young people with their research, as shown in figure 4.11. Those who answered 'other' to the question about drawbacks, and so might have voiced these concerns over negative impact on scientists or students, were not included in the groups who responded that they are personally not well equipped to engage young people, or those who did not know how to answer. This implies that the concerns are raised by those who feel confident in their outreach skills.

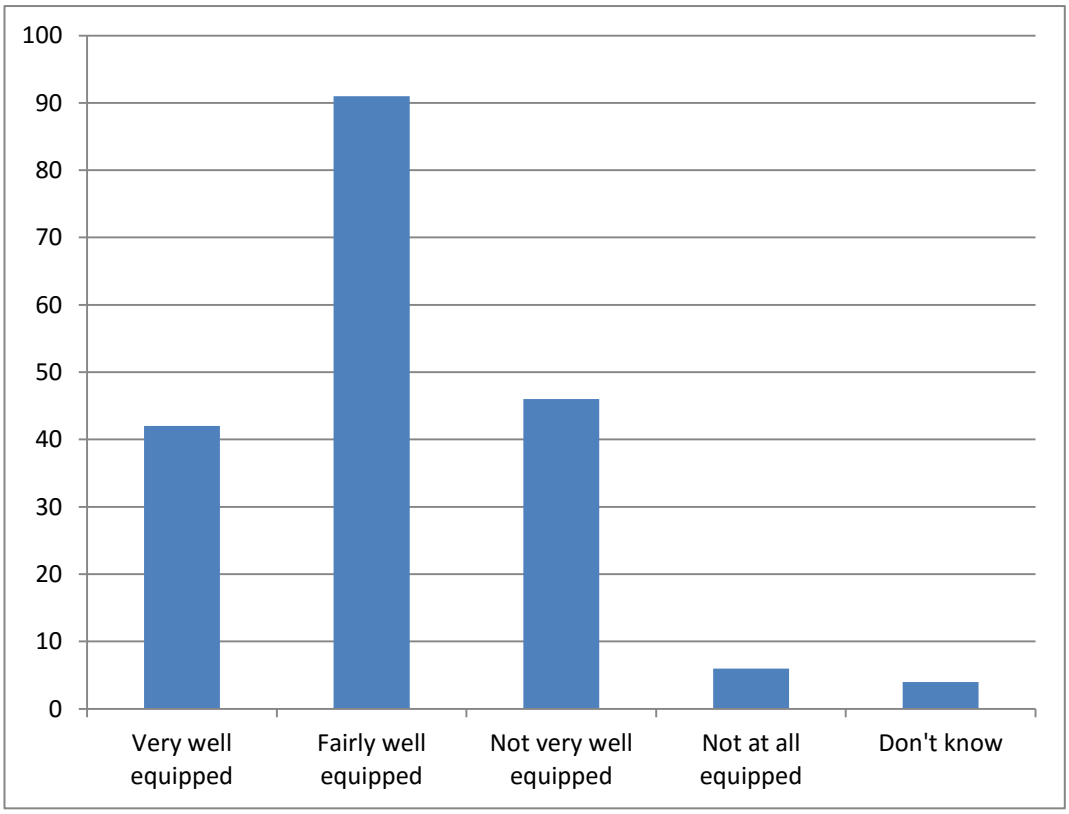

Figure 4.11: Responses to the question 'How well equipped do you personally feel you are to engage with school-aged young people about your research?'

It is interesting to me to explore where this confidence in their skills comes from. Only 26 respondents indicated that they had experienced training in how to work with young people both in and out of schools. 14 respondents indicated that they had been trained to understand the UK education system, and nine of these overlapped with the respondents trained to work with young people. If only 31 respondents have experienced any

training in this area, then the majority of those who feel confident in their skills in engaging young people are picking up this confidence from other sources, such as feedback from audiences or peers, or innate self-belief. This is a theme I will look as I go on to present the findings from my outreach activity observations and the follow-up interviews.

4.5 Summary

Having established that this group of respondents are likely to be active and supportive of outreach generally, we can see that for the physicists outreach is an area of much confusion and doubt. Systems for support are generally lacking, and there is a tension for many around how they balance the various demands on their time. Young people are a valued public, and in this instance can be considered an audience as much of the activity considered to be covered by the term 'outreach' is transmissive in nature; information is given to them by the participating physicist who assumes, rightly or wrongly, that this audience is somehow lacking in knowledge, skills, or suitable role-models. Having looked as broadly across the universe of UK physicists as was possible, I will now move on to look more closely at the action of physics outreach and the behaviours and perceptions of the physicists involved.

Chapter 5: Outreach activity observations

5.1 Introduction

In earlier chapters I have explained my desire for this study to look at outreach activities, using my professional experience and background, and develop a deeper understanding of physicist perceptions of these activities. The survey findings discussed in the previous chapter demonstrate a wide view of opinions even within the restricted population it reached. In this chapter and the next I look more closely at a series of outreach activities and the physicists taking part in them, to look for themes in behaviour, style and beliefs from the physicists involved. This chapter looks in depth at the activity observations I carried out. Through discussion of these observations I will address the first and second of my research sub-questions, providing a local focus to my consideration of the contexts within which outreach takes place, and the people involved.

The series of outreach activities I observed, shown in table 3.1, section 3.2.2, can be considered in the first instance to be relatively similar. Each event lasted between one and three hours, with the direct contributions of the physicists involved lasting between 30 and 60 minutes. Each involved a physicist speaking to a group of people who are not physicists, and for the main part these people were 18 years old or younger. Because the main element of the physicist contributions is as a speaker, even the formats ended up quite similar in many respects, involving presentation slides in some way and a quiet audience. Sometimes these talks were augmented with other elements such as videos or practical activities, but even activity 8, the Chaos Theory play workshop, included elements of a traditional talk, although supplemented by class activity. Activity 2, the Cosmology Masterclass, included a ‘Meet the Scientist’ session where students could informally meet PhD and post-doctoral physicists, but this was too loosely organised to permit formal observation and follow up. The schools lab practical element of activity 5 was delivered by a retired teacher who did not identify as a practising physicist and so did not meet the parameters of my study; my focus at that particular visit was a talk by a particle physicist included in the programme for the day.

Videos or animations were used in eight of the twelve talks, and failed to work first time in almost every instance, whether the speaker was used to their environment or not. In some cases significant time was spent waiting for technology to be fixed, or large chunks of the planned content were skipped due to the failure. In these cases it was often unclear what the video would have covered. The most confident speakers were those with considerable experience in outreach or teaching and tended not to rely on videos and animations. The notable exception to this is the mobile planetarium activity, where the speakers were experienced and confident, but video and animated content was central to their delivery. Having highlighted the similarities, my experience of these activities was remarkably different from event to event, and this starts from the point at which I had arrived at the activity and my interactions with the audiences, outreach officers and physicists began. These different stakeholders between them carry out a variety of different roles in making an outreach activity happen, as I shall explore in the next section.

5.2 Roles within outreach

Most outreach activity involves three key stakeholders groups, to varying degrees: 1) the audience, a group chosen to be targeted by any given activity, often schools; 2) a participating academic, who is representing elements of their research area; and 3) professional outreach organisers and managers such as outreach officers or widening participation teams. Accordingly, I arranged the activity observations for this study through outreach officers, a teacher, or directly through the participating physicist as outlined in table 3.1. The joining instructions I received varied widely from event to event, and determined both how I arrived and started my observations. These starting points provide an insight into the different roles found in any outreach activity; much can be determined from how the various stakeholders start their interactions with me and with each other.

For the events that had a public audience as well as a schools audience my instructions were no more than a normal audience member might have, and so I duly turned up at a venue at a given time and place. These events were all in the evening, free of charge,

and ticketed but with the option to turn up on the day. For any event the audience experience starts well in advance of the content delivery and I found that my observations of these events naturally started as I entered the place where the activity would be delivered, as the following example shows. Here, as for the rest of the chapter, I use a section of my field notes to elucidate my findings; the number to the left is the index I used to keep track of my notes and coding, as explained in section 3.2.3. This extract shows my arrival at Historic University for an evening lecture:

> 3.01 Cold dark evening as I arrive at Historic. Taxi driver drops me off at the main building, and the lecture building is just behind it, starkly new compared to old main building. Students are still milling around campus. The lecture building is well signposted and well lit, and I'm greeted at the door by someone checking a guest list who gives an introduction to the event.
>
> 3.03 Wil greets me near the entrance to the lecture theatre and introduces me to his fiancé and friend, both here to see the lecture.
>
> 3.04 Wil: "I'm very nervous that you are here, you know". I ask why. "You're my boss's ex-boss". I explain that that's not the hat I'm wearing tonight, that today I'm just any other PhD student. Wil responds "I guess …".
>
> 3.05 Wil goes on to mention that he won't be using demonstrations in this lecture and that this also makes him nervous. "I have nothing to hide behind …". He goes off to prepare and the final guests arrive.

Wil is an outreach officer, and in this case also the main presenter for the evening. He self-identifies as a physicist and Outreach Officer, although he is on a professional contract at Historic. The person who met me at the door was a student, performing event management tasks but managed by Wil. I already feel comfortable on site because of the event signposting and lights, important as this particular university is reasonably secluded, although not a traditional 'campus' university. Such elements set the tone for any event, and as Wil is the speaker it makes sense that he would want all elements to provide the best possible context for his presentation. Whilst in extract 3.04 he makes a joke of being nervous because I am present, by extract 3.05 I realise that he is generally nervous, feeling somewhat exposed in an environment where his peers, managers and other academics from the department will be in a position to critique his own understanding of physics, and I later notice that there are several professors and the Head of Department in the audience. He later remarks on his own role at the event:

3.07 Wil introduces himself and the lecture series. “It’s my job to introduce the speakers, and normally now I’d be telling you how clever they are, but that seems a little uncomfortable to do for myself.”

The dual role of presenter and officer here is shown to be in tension, and Wil’s reluctance to assert his own knowledge reflects an element of imposter-syndrome that I have experienced in many of the officers I have managed over the years. In the case of this particular event he is responsible for so much in one evening: the audience, their experience, the staff working the event, the technical elements, logistics and the content and delivery, yet this work can go unrecognised.

While it is common for the outreach staff to facilitate an event rather than to star in it, this is not always the case, particularly where an officer has specialist skills that the participating academic might not be expected to have.

7.04 Kate is entertaining the audience while they wait. She is clearly a practiced compere.

7.05 She asks the audience if they know any space jokes. I assume that she has run out of material, but that she is also trying to keep their attention as the last technical elements are put in place. It is very cold and dark, but her team are seating the smallest on cushions with blankets, and hot chocolate is available at the back.

7.06 Kate introduces the speaker ‘Alexander, a professor in the Industrial physics department’

7.07 Alexander is already holding his microphone and takes the stage, thanking Kate for organising everything and introducing him, and asks for a round of applause for her. He is very confident with the microphone, which I’m surprised by as they can be off-putting if you are not used to them. It’s also very unusual for the officer to be thanked at the event, and so I'm pleased to see Kate get the recognition up front.

In taking on the role of host and entertainer Kate sets the tone for this event. The families and students who are present are mostly standing, outside in quite uncomfortable conditions. This is demonstrated by the effect the conditions had on my notes for this event, the cold and dark hampering my ability to write. For the audience, this is somewhat compensated for by the blankets, hot chocolate, and entertaining start to the event. The audience are interacting with Kate as presenter, their input has been welcomed and this puts Alexander in a strong position to start his presentation, despite the inclement conditions.

Having considered the roles at the events considered public, it is useful now to focus on how roles within outreach are different in those events open only to schools groups. Staying with Industrial University, Kate's role in the events of the day started much earlier that morning:

> 6.01 I meet the outreach officer, Kate, at a train station and travel out to Industrial with her. On our way onto campus we stop off at a shop to buy milk for one of the demos. Kate describes the day ahead, explaining that there is a second event on this evening, so she has many rooms that all need to be readied at the same time. We head into the department, and I take a seat in the seminar room for the first morning session. The first speaker, Armin, arrives 20 minutes before the session is due to start in order to set up, and I introduce myself to him.

Kate is technician here as well as looking after logistics. This is demonstrated again later in the morning, during the first presentation.

> 6.11 Kate is sat to one side trying to load up a YouTube video, it's not working, and Armin keeps coming back to her to ask if it's ok now.

Not all of the academics will need or even want this support. I noted in extract 6.01 that Kate and I picked up milk on our way onto campus. That was the single concession made by our second presenter, Marina, to letting Kate help with the delivery of her medical imaging session. I will come back to the demonstration later, but for now I note that Marina has assumed the role of technician for this activity, and is even quite controlling of her environment as shown in the following segment, where the visiting young people are taking part in a practical demonstration of ultrasound imaging:

> 6.47 Marina interferes with the positioning of the sensor, holding the hands of the student and positioning them for a better image. The process of letting the student try, and then Marina taking over is repeated as each student tries to find an animal:
>
> 6.48 Eventually she shows them the empty tub and animals.
>
> 6.49 The teacher tries to wipe off the transducer, but Marina fusses around her, and eventually takes it from her, 'no, no, I will do this, it's ok'.

The teacher accompanying the group in this session was proactive and engaged throughout, keen to help her students get the most from their time there:

6.30 Kate introduces Marina, medical physicist. The teacher explains that this session is going to be useful for the next assignment they are going to do.

This sort of expectation management for the group can make a difference to the student experience, but across the events it was clear that not all groups get this from their accompanying teachers. From the physicists' perspective their interaction with the audience does need to include some elements of expectation management and understanding of the audience needs. Sometimes, as in 6.30 above, there are intermediaries such as the teacher but otherwise this role must be taken by the physicist or outreach team in support and forms part of their hosting duties.

Understanding the audience's needs can mean changing your delivery for different groups, something that is not easy when your content is mostly fixed, like in a mobile planetarium show. I saw two such sessions back to back; the first was with a year 10 group, the second with year 9. Here we see that the content is amended to suit the group.

4.30 Last session of the day is year 9. They are much more lively on their way in. Jenny checks the age group, and chats to Rob about what to cover in the session.

4.31 Jenny: 'These are year 9 so we should switch to life cycle'

Jenny is an outreach officer. The size of the planetarium means that it takes two people to move it around, and to supervise the activity. In the case of an emergency Jenny and Rob between them would flip the planetarium over, releasing the students to follow normal emergency procedures. It's also a very technical set-up, requiring arrangement of lenses and the projector. Jenny is an experienced planetarium presenter, and here she takes responsibility for making sure the level is right for the audience. In extract 4.31 she is referring to the life cycle of stars, something that the year 9 class are likely to have recently covered or will do soon.

Throughout all the different roles described there is one that is less overt, yet implicit in any outreach activity. Whether the activity includes a remit for recruitment or not, the presenter is in part a role model for the audience or, at the very least, is an advert for their subject area. In the instance that follows, we see that this can add tension to the delivery for the physicist:

8.03 Mike: ‘I’m Mike, I’m a physicist at the Cathedral University. I’m a materials scientist, not a chaos expert, so I’m as out of my depth here as anyone.’

Mike has happily signed up to be part of the development of this play, and by all accounts was comfortable with his role in the public performance. Here he is apologetic, no longer an expert but still in an expert role. Others are surer of their relationship to the content:

9.29 Jonathan: ‘So you’ve heard the history, now for the advert and propaganda. I’m a string theorist … we’re not sure that string theory answers this, we just think that it might.’

Mike, in 8.03, uses shared uncertainty as an opportunity to develop a bond with the audience, from a position of shared understanding, or lack of it. In the case of Jonathan in 9.29 he’s clear that his role here is in part to sell his subject, or an interest in it, and the uncertainty he presents opens up the future of physics to be something that is yet to be determined, an opportunity for the audience to get involved.

5.3 The value of outreach

The teacher’s efforts to support the presenter, shown in extract 6.47-6.49, raise another consideration of these activities. This teacher clearly values the time she, and her students, are spending in their activity. Marina, the physicist, also clearly values their time together, as she has put considerable effort into making her presentation work well. The sessions are valued by both presenter and audience throughout the observations, some indicated by an element as simple as location:

1.06 We’re taken up to the room. The science club have special dispensation to use the college boardroom, part of the principal’s suite. There are refreshments at the back of the room. The teacher is keen to get the kids in so they are not clogging up the corridor outside the Principal’s office.

For this 6th form college their Science Club is afforded a status of importance by the location offered for the session. The teacher is very aware of her location, and is keen to get us all, and the students, into the room to prevent disturbing others working in this area. The refreshments are tea, coffee and cakes for us and for the students, to top up the

lunches they were invited to bring in with them. This element of luxury helps the students to know the teachers take this event, and their participation, seriously. Refreshments can make an audience feel welcome or more comfortable, as with the hot chocolate mentioned in extract 7.05, or as in the following extract where the provision of small comforts such as lunch is one way in which a school can thank a presenter for providing an activity:

> 4.1 It's a sunny, but quite cold, day. I was delayed by issues on the train line. Jenny takes this in her stride, and I join part way through their day, toward the end of session 2 of 4.
>
> 4.2 As the session closes I see a very animated class asking lots of questions. The planetarium team and I are brought lunch by the school Science Enrichment lead, Grace, who has arranged the session for her department.
>
> 4.3 Grace introduces me to the Head of Science, and they go on to tell me how well pitched they think these sessions are, and how useful they are to the students.

Grace holds a role that manages the provision of science enhancement activities for her school. This means that there is someone dedicated to making arrangements and managing contacts, something which not all teachers have time to do. However, as with any case where the organisation of an activity is not carried out by those involved in the session itself, it can be difficult to ensure that all those taking part in the final activity value the experience as much as others do. In arranging events for multiple school groups on campus I have experienced a recurring issue with school trips that not all the attending teachers are equally as keen to be at any given event, in some cases because they are asked to support a trip outside of their subject area, but where it is their subject area if it is booked by someone else they lose control over their choice to attend and so become disenfranchised. In the case of this activity, the same is true for the teachers bringing their classes into the planetarium sessions.

> 4.16 The [planetarium] door makes a rustling sound, and the teacher tells me a student may be trying to join us late. I let Jenny know, and we move to let her in.
>
> 4.17 Towards the end of the video the kids are chatting more, and giggling. The teacher is unsettled, fidgeting a lot, and not doing anything to settle the kids.

A mobile planetarium show like this starts off with some standardised content, in this case the 'We Are Astronomers' show, lasting about 20 minutes and narrated by David Tennant. This is followed up by live content from the presenters. Whilst I have not focussed on the behaviour of the audience in my observations, during the video show I could not observe in any detail the delivery team, so I was drawn to the teacher and students. The additional arrival to the session was extremely disruptive; the planetarium is a large inflatable, so any movement is felt by all those enclosed, and is noisy. The teacher should have warned the delivery team that the student would be joining us late, and encouraged the other students to leave room for her so she had somewhere to sit when she arrived. One of the roles of an attending teacher is class behaviour management, but this is sometimes not understood in an outreach context; classes can become unmanaged or in some cases the outreach officer or physicist take on this role. In extract 4.17 I felt the lack of response from the teacher was worthy of note; the teacher sets the tone for the young people, and has significant influence on the experiences of the group they are with and the participating physicist, for the better as well as the worst:

> 1.36 The host teacher leads the group into discussion to see if there is interest to take part. Two groups of students are clearly discussing their ideas, and the attending teachers go up to the front to ask questions. Alice is more animated now, in a 1-1 situation, but still fidgeting and pacing. The students eventually follow suit, and ask questions about how to do well in the competition.
>
> 1.38 The students leave, Alice asks the teachers 'was that the right kind of level?' Response 'Oh yes, it was fine.' They lead us out.

By being interested, and leading by example, the teachers enable the students to engage with the topics being covered by the physicist. In this instance Alice's request for additional information about her performance is met by a reassurance and encouragement, part of the teachers' being grateful for her input. I personally disagreed; her content needed more thought and interpretation for the students, and without the teacher guidance I do not think the students would have understood how to engage with the competition elements. But, as will later come out in the interviews as well, Alice definitely understands that what she is doing has the potential to have positive, or negative, impact on her audience, and she is willing to seek advice on how to improve.

5.4 Education vs. Entertainment

My interpretation of the teacher role in helping the students to engage with the outreach activity is inherently values driven. It's my role to help outreach activities be as productive as possible for all involved, and so to see activities occur where the audience does not, or cannot, engage is frustrating and a call to action for me. I should not assume, however, that this is well understood by the audience, whether they be teachers or students. Outreach is not assessed, and the terms under which any audience attends are different depending on the way it is advertised, recruited to, booked and delivered. Whilst I overlay learning goals onto the activities, this does not mean that the audience or presenter has given this any great consideration. Extract 1.38 above shows that at least some of the presenters are thinking about these issues. I will go on now to reflect on the tension between outreach as education and outreach as entertainment in the activities I observed. In practice this tension is most clearly identified in the behaviour of the presenter:

2.46 Bill sets out some grounds rules for his session, explaining what he is going to do and how the students should behave. He's moving animatedly as he speaks.

2.47 'Don't worry – I'll explain everything as I go along.'

2.48 'There are two rules in my talks. The first, ask questions, whenever. Feel free to interrupt. The second, laugh at my jokes'

2.49 Student: 'How do we socially inept slightly autistic types know what is a joke?' Bill: 'That doesn't matter. Someone will know if it's a joke. So if at any point any of you think I'm trying to be funny, or you think I was funny, give a chuckle, and everyone else can join in.' He moves on his slides, and presents the topic for todays talk.

Bill is a very experienced lecturer, and one of the most relaxed of all the speakers I saw. In this extract he is trying to enable behaviours in the audience, and manage their expectations of the talk. He wants them to take as much as they can from their experience, but he also wants them to enjoy it. I would not normally expect the presenter to face the sort of audience response that he received in extract 2.49, but he dealt with it well. I later found out from the attending teacher that this particular student was both gifted and had an autism spectrum disorder.

It is reasonable to hope that the audience might enjoy a talk, particularly if they have chosen to be there and so might already be interested in the content. However, expecting the audience to enjoy a talk or be entertained by a talk are different goals, and expecting an audience to be entertained if they have not chosen to be there sets a very high standard for the content and delivery. In the extract above Bill mentions his intention to include jokes. Being funny does not come naturally to everyone, and whilst it is something you can learn techniques for it is not easy to interweave comedy with your other learning aims for a presentation, even for those who are trained in comedic delivery. So this pressure to be funny as well as pass on their physics content is difficult for the presenters. There is also a difference between comedic delivery and the telling of jokes; the former might rely on timing and pace to convey a feeling, the latter requires shared frames of reference for content and for any given audient to find a particular reference amusing, as in the following extract:.

3.13 Wil: 'Physics reveals beauty'. Slide shows a picture of a metal surface at approx 15 nm scale. 'I can't explain all of this unless you want to sit down and do maths for the evening, which I'm guessing you don't want to do'

3.14 Wil: 'Now you guys probably don't find this image as beautiful as I do. I have had the chance to explore the science here, and find the beauty inside the system through physics.'

3.15 Wil: 'Now this pattern may be familiar to you'. The slide changes to a picture of a bowl of Cheerios. 'Here's a picture of my tasty breakfast'. The audience laughs

The first image of the metal surface was complex, and Wil adds to that feeling through his statement about doing a lot of maths, something I will return to later on in this chapter. Wil uses a simple common reference in the bowl of cereal on his slide, shown in figure 5.1, to make his point. The laugh comes from the relief of recognition and the timing of his changeover of slide. The image still exhibits the phenomenon he is demonstrating, in this case mathematical patterns found in nature, but is familiar to everyone in the room.

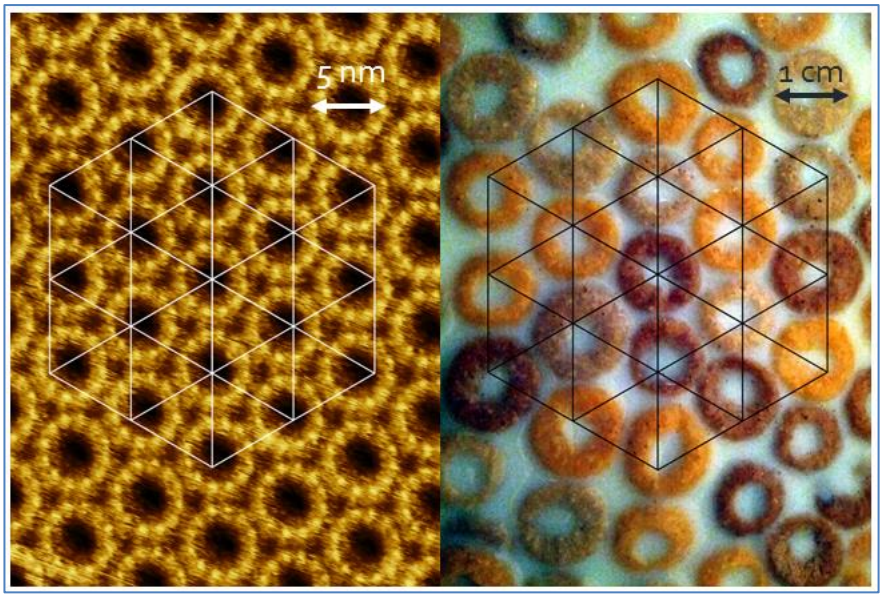

Figure 5.1: Slide from presentation given by Wil, a physics Outreach Officer, during an observation of an outreach activity. The image shows similar patterns occurring at the nanoscale on a metallic surface (left) and in the more familiar bowl of cereal hoops (right).

This instance demonstrates that the simplification of a topic does not mean that it needs to be dumbed-down, a common misconception raised in the survey responses in chapter 4. Simplifying complex subjects, however, is a skill and takes time and thought. In the following extract Vincente has employed the help of others in seeking simpler explanations he can use:

> 5.24 Vincente has reduced the search for the Higgs boson down to a search for missing mass, using a Lego-based animation[10] to demonstrate parts of the processes involved in his research.
>
> 5.25 He tries to show a PhD comics strip video[11]. 'My laptop is poor, I hope you can hear' to explain how particle smashing created new particles.
>
> 5.26 The video moves fast, is difficult to hear and deals with complex material. Every 30 seconds or so he fast forwards a chunk. He re-explains what we saw, explaining that the new particles are caused by 'magic'.

English is not Vicente's first language, so this may be adding to the difficulties he faces. In this instance his reliance on externally produced videos means that they do not

[10] https://www.youtube.com/watch?v=Ts7bQ9wsmHM
[11] http://www.phdcomics.com/comics.php?f=1489

convey exactly the messages he wants, but he seems adamant that they are the best way to engage his audience. Several of the videos he used come from the web comic 'Piled Higher and Deeper' (PhD), which describes itself as 'the comic strip about life (or the lack thereof) in academia'[12]. As such the audience is postgraduate students, so the content is not designed for an audience of 14-17 year olds. In the 45 minute talk Vincente has over 35 minutes of video lined up, although by skipping whole videos and fast-forwarding he only shows around 15 minutes in the end.

Whilst I have shown the difficulties that use of videos and animations can present to a talk, the planetarium sessions demonstrate that well thought out, pre-prepared and pre-delivered content can be highly effective in the right circumstances.

> 4.18 The show [We Are Astronomers] is well written with nice animations, but I personally find it difficult to concentrate on the film, and have to tilt my head at an awkward angle to watch it. The students are doing much better at concentrating than I am.
>
> 4.19 Rob uses the end of WAA to link to talking about aurora. He mentions a student he knows at City University who videos aurora on a snow mobile, carrying a rifle in case of dangerous animals
>
> 4.20 He goes onto explain the different colours you see in the aurora based on the elements in the atmosphere, and explains that they can view this themselves under particular circumstances. He uses this to link to the next section of the show, where they'll be discussing what can be seen in the sky tonight.
>
> 4.21 Jenny: 'We're going to be using Stellarium for the next section, but you can also use free apps that are available online or on your phones'

The level of the content in *We Are Astronomers* has already been carefully managed, and the delivery team knows how it is targeted. Rob ties the ending of the film back to research from his own department and adds information about the phenomenon shown, in this case auroras, because he and Jenny think the students will understand the additional information. The presenters link the content in the video to current research, and to the next element of their show. Whilst this second element, looking at what can be observed that evening, uses a programme called Stellarium, it is presented by Rob and Jenny, using the programme instead of slides. The fact that the students could

[12] http://phdcomics.com/about.php

access the programme through their own devices as well is a nice touch, although I would feel more confident that the students might go on to use it if there was some time dedicated to showing them how to. Stellarium contains pre-programmed elements to help the user to identify different constellations as seen in this segment from a later session with year 9 students.

4.43 Watching tonight's night sky on Stellarium. Rob removes the Earth's atmosphere from the shot to show why we locate telescopes where we do, and the class make an audible 'wow' sound.

4.44 The constellations are shown at this point with cartoons overlaid to show their names. 'Has anyone seen Clash or Wrath of the Titans?'… there is silence from the group, and Chris stutters to fill the gap, going onto explain some of the myths behind the names. The students do not respond much to the Greek myths, so Jenny talks about Ursa Major as the Big Dipper or Plough instead. With the students not responding they move onto to identifying their favourite constellations.

4.45 Rob talks about Orion, his favourite constellation, and how you can see the life cycle of some stars within this constellation. He relates this back to supernovae and his own research.

4.46 The students move outside again, and Rob continues to answer questions that started in his conversation about his own work. The questions are readily offered, and good, based on what they have heard.

Again, the fact that Rob relates the content back to his own research is successful, and triggers interest in the audience, who are asking questions about Rob's research, rather than about the film or Stellarium presentation. This extract also highlights just how much time in a mobile planetarium show is spent covering fundamental physics and astronomy, or associated facts, rather than concentrating on the presenter's research. The stories of the constellation names based on the cartoons overlaid in Stellarium, shown in figure 5.2, had some engagement from the group but were not very successful. This was perhaps because the students were from a variety of ethnic backgrounds, or just the result of a lack of awareness of these stories that those of us interested in astronomy might take for granted. In trying to engage the group with the Stellarium content Rob attempts to relate content from the show back to an element of popular culture, but it fails. The films *Clash of the Titans* and *Wrath of the Titans* were five and three years old at the time of the observation. Despite the relatively successful box-

office figures for *Clash of the Titans*, given that both films are classified '12' it is not reasonable to expect a group of 13 year olds to have seen them.

Figure 5.2: Image from the programme Stellarium, showing various constellations with cartoon images of the Greek myths they are associated with overlaid

By offering up cultural stories or interests such as films as a way to connect, it can be seen that the presenter is trying to create common ground with the group. What matters more than the chosen content here is the presenter's ability to adapt to the response of their audience. This is not easy to do in a lecture or planetarium environment, where lights might be dimmed and the audience only partly visible. Unless they are core to the content of the talk, such as the cereal example given in extract 3.15 above, it is important not to let popular culture references dominate the way the talk is going; otherwise they run the risk of taking attention away from the rest of the content:

> 9.12 Jonathan: 'Or indeed if you've seen 2001, with the rotating disc, or the more recent one with Good Will Hunting in …' There is a pause while he tries to remember what I assume is a film name. 'Come on, someone …' Another pause. Audience: 'Interstellar'. Jonathan: 'No, not Interstellar'. Another, longer, pause. After about a minute I offer up the

film title: ‘Elysium’. Jonathan: ‘Exactly, with the rotating habitat!’. He carries on, not explaining why the film link was important.

Here Jonathan starts out explaining a physical property through an image he hopes the audience carries with them. He does not have a slide with the images of the spacecraft, or a diagram of the phenomenon he’s describing. Given the mention of the rotating habitat I can infer that he was describing artificial gravity as a result of centripetal force in a spinning, round, spacecraft. He is in the middle of talking about Einstein’s ‘discovery’ of general relativity, and goes on to describe latitude and longitude lines on spherical and then toroidal shapes, but I do not manage to establish what connection he was trying to make to the spacecraft in the films he mentions.

5.5 Talking about physics and mathematics

So far I have described several of the ways in which the presenters tried to supplement their descriptions of physics and the mathematics which supports it. However, the bulk of the content I saw was direct explanations of various phenomena. In this section I am particularly interested in the ways in which speakers referred to physics and maths as research or subject areas. In the case of Jonathan described above, he has positioned Einstein as making a great leap of intuition before then trying to explain the subsequent theorem:

9.10 Jonathan: ‘There are some things in physics where I think I could have done it if I’d been alive at the time. But even had I had all the information Einstein had at his disposal, all his books and him whispering in my ear, I still couldn’t have made the connections he made.’

In this segment he is showing his respect for Einstein’s ability, and letting the audience know that to be able to put these thoughts together the way that Einstein did is remarkable. Without saying it explicitly, this lets the audience know that it is ok not to be able to do this themselves. He later goes on to describe the nature of scientific research:

9.23 Jonathan: ‘But that’s not enough for physicists, we have to really know, to confirm it.’

9.24 Jonathan: ‘So this is an approach to science, “We've got this law, it doesn’t work very well, the data doesn’t fit, so we’ll change this number”. This is an approach, but it didn’t work.’

Jonathan is keen that the audience take away the sense that the science is not yet done, and that new approaches are welcomed, and needed, to make sure we are confident in the assumptions we make about the universe. This spirit of science comes through in several of the talks:

5.30 Vicente: ‘The theory of particle physics that we use these days is the most complete we have ever had. But we know it only explains 5% of our universe. This is embarrassing.’

5.31 Vicente: ‘It’s a whole new journey!’

5.32 Dante’s Inferno quote on the slide, reference canto XXIV

Vincente presents a quote in Italian that sums up for him the scientific endeavour and includes an aspect of recruitment to science; this is a segment from Dante’s inferno[13], in which Ulysses recounts his calls on those around him to better themselves and continue their quest for knowledge.

Whilst moments of inclusivity like those just mentioned occur in many of the presentations, they do not indicate the overall tone of most of the presentations. There are no instances of a deliberate exclusion of the audience, but I am concerned by accidental exclusion that might occur due to descriptions of researchers and research. Such a barrier might be caused by negative language, as seen here in the workshop delivered by Mike, a physicist, and George, a science communicator:

8.11 George: ‘You may have heard of Lorentz … [6 minute history of the scientist Lorentz] … he wondered could a butterfly flapping their wings in China cause a tornado elsewhere in the world? No one else has followed the action through to see if it might happen, so this is what we’re doing. To make sure there is some physics in it we have Mike to be here as Lorentz, to respond to my character, Josh the ignoramus.’

Here the play deliberately sets up a situation where there is a scientist and someone who could be considered to be of the general public, in this case known as Josh, the ‘ignoramus’. This puts a gap between the scientist and Josh, and is a deliberate ploy to

[13] The full quote, and a translation, can be seen on page 21 at the beginning of this thesis.

allow basic questions to be asked of Mike/Lorentz, but I note my concern that this could easily turn to making science look overly difficult or scary. This concern is validated slightly later:

> 8.16 Mike: 'Here are the keys to your flat. I'm going to drop them. What happens?'
>
> 8.17 George: 'They fall, what about it?'
>
> 8.18 Mike: 'They fall differently, the laws of physics took over the minute I let go. The keys fall in different ways, landed in different places.'
>
> 8.19 George: 'It's random.'
>
> 8.20 Mike: 'It's deterministic. There are a variety of factors that change the way in which the keys fall. How's your head?'
>
> 8.21 George: 'Not exactly hurting, but spinning.'

The conclusion of this section of their performance is that by experiencing the explanation of the phenomenon shown, the ignoramus character feels uncomfortable. Whilst in the context of the play such a divide is a deliberate plot device, for many of the speakers similar language occurs without thought for the consequences it might have:

> 2.50 Bill: 'I thought I might as well scare you on the first slide …'. The slide shows the Friedmann equation.

Here Bill makes an offhand remark about scaring the audience, but I find it unlikely that he would actually mean to scare them. Such a comment could reinforce external messaging about the difficulty of maths and physics. It is understandable that he might expect them not to understand the maths behind the equation yet, but there is no need for the presentation of an equation by itself to be scary. Later on he presents some mathematical manipulations:

> 2.56 Bill: 'If I stretch these curves, and squish these curves, I can plot them all on one graph' He's showing a series of spectra, and trying to superimpose them on one another. I hear the kids whisper 'That's cheating'.

The students respond to what he's doing, but do not ask him to explain. The maths here is black-boxed; by not explaining why he has been able to manipulate his data in the

way he has, Bill leaves the students feeling confused. Avoiding such explanations could be caused by several factors: the presenter may not feel there is time to go into detail and so the explanation is removed; the presenter may not feel confident in explaining the phenomenon at a basic level and so avoid explaining it at all; or the presenter may just not think it's important to explain the detail, as shown by Wil in extract 3.13 above. The difficulty with this last situation is that the audience, as in extract 2.56, will pick up on aspects of the talk where they feel they have been misdirected in some way.

Even when explanations are given well, it can also be the case that oral description alone is difficult for the audience to work with. Slides are an opportunity to support explanations, as are props, but in many cases both could be improved:

> 2.24 Jonas: 'If I put a stone on a rope I know I need to apply force to rotate it.' Jonas is miming the rotation of a weight on a string.

Here a simple prop would have given Jonas something to talk about, but instead he is spending time trying to convey his image to the audience through hand waving. In trying to describe mathematical constructs of the universe Jonathan similarly has trouble:

> 9.32 He's talking about geometry and space that joins up, grabs a reserved sign to use as prop, he's discussing wormholes at this point, his pace has slowed down and he's saying 'erm' a lot.

In this extract I am having trouble following Jonathan's talk as he moves between concepts; until this point his delivery has moved at speed but now he has slowed down as he becomes uncertain of how to make his point. He used the 'reserved' sign, an A4 sheet of paper, to create a Moebius strip, and talked about an inflating universe and toroidal space; this could all have been improved by the planned use of props such an inflatable toroid. His next slide includes images of Klein bottles, and it is now easier to see where he was trying to take us in his descriptions. I acknowledge that as an outreach professional I know where to obtain props such as torus balloons and Jonathan might not; however, it seems reasonable that he might have planned to have paper, scissors and tape on hand to create the Moebius strip, and he has access to an outreach officer, who could have helped him to procure any props he might need. In both the examples of Jonas and Jonathan, and indeed through most of the presentations, I can only assume that lack of time to prepare has been an issue when it comes to developing good

explanations of complex subjects, giving thought to bias that might be unconsciously presented to the audience, and fundamental elements such as slide preparation and prop procurement, based on the literature and my own survey.

5.6 Summary

The activity observations discussed in this chapter have highlighted the practical considerations of outreach, such as the many different roles that must be enacted, and the difficulties that are faced when trying to explain technical and abstract concepts. I have shown that the issues that physicists face when considering their participation in outreach, such as tensions between what the audience want from outreach, and what the physicist enjoys or feels comfortable delivering, are evident in their delivery of outreach, and can impact on the audience experience. I shall go on in the next chapter to present the interviews that followed each of these activities, to explore the physicists understanding of both their delivery and the wider contexts of outreach, before going on in chapter 7 to draw conclusions about how the physicist perceptions of outreach influence their delivery and success in outreach.

Chapter 6: Reflections on outreach from the participating physicists

6.1 Introduction

My main concern throughout this study of outreach has been the perspective of the presenter. Having attended a range of outreach activities as a spectator, trying to locate myself in the conceptual space between the presenter and the audience as discussed in section 3.1.3, I have been able to provide a very particular perspective on the factors that are influencing outreach delivery, informed by my position as a physics outreach specialist. In this chapter I present the results of a series of semi-structured interviews with the physicists following the activity observations, asking them to reflect on the activity they took part in, and the wider context within which they undertake outreach activities. The full data collection and analysis process can be found in section 3.2.4, and an overview of the participating physicists and institutions seen in table 3.1. By looking at these perspectives of outreach I have begun to answer the second of my research questions, and develop an understanding of what successful outreach looks like to the physicists involved. Below, I present the interview data; each respondent was very thoughtful in their discussion of outreach although, as we shall see, their motivations and understanding of the wider context within which they are an actor were very different.

6.2 Motivations for getting involved

As has been mentioned in previous chapters, these physicists are already inclined towards outreach to some degree, proven by their taking part in one of the activities I observed. This does not mean, however, that the choice to get involved in outreach is an easy one for them. As we might expect, participants stated a range of reasons for involvement and these were similar to those presented in the survey data discussed in sections 4.3.1 and 4.4. The interviews allowed a chance to develop some of these

reasons further through conversation, as shown in the following statement by PhD student Rob:

> I think if you are being funded out of tax payers' money then you should give something back because as a PhD student I don't pay tax. It is difficult to say how my research affects the everyday man. I don't build something you can sell in a couple of years. I look at the universe and answer questions that don't really affect everyone's everyday life … If you do outreach you are sharing your enthusiasm for the subject with someone and they might be happier to see their tax bills are going towards science research. I think that is important long-term even though it doesn't have many short-term benefits.
>
> (Rob)

Rob presents a sense of duty to the public as his motivation for getting involved in outreach, but it is overlaid with issues of the nature of research funding, and implies the pressure of the impact agenda even though he does not reference it directly. Rob suggests that through outreach the public might be better convinced of the value of science. This concept was expanded upon by Armin:

> Nowadays it's time for all the scientists to come out of the rooms they have or their computers and try to talk to people. The impact that they could have on the public, and the public could have on their work is huge. I'm talking really about funding. If the public know about your work, they could put some pressure on the government and you could get more funding on the work you are doing.
>
> So, it's important for the scientists to talk about their work and the importance of their work to the public. You have to try to sell your work. Everyone is doing that and scientists have to do better than they are doing now.
>
> (Armin)

Armin directly relates funding for science to public approval, hoping that by better informing the public it might be possible to place them in the role of advocate for science.

Duty to the public in some form or another was inherent to all of the responses but duty to their institution also appeared, particularly with respect to recruitment issues. Here Wil, an outreach officer, describes the tension he feels between getting his audiences interested in physics versus recruiting them directly to his institution:

> So, yes I like to think of it more that I am here to try to get more people into physics generally. The end result of that probably will be hopefully more people coming to do physics in Historic but that is not necessarily what I set out to achieve in an event. I set out to achieve an event from a good outreach point of view, whether that is a widening participation event or a public engagement sort of event. And I think the recruitment should probably really follow on from that, it is not [pause]. I think when you start trying to aim for recruiting x number of people from an event you are going to probably give a bad event.
>
> (Wil)

Whilst Wil might be expected to feel pressure to recruit due to his job role this sentiment was expressed by several of the other respondents, particularly the PhD and early career researchers, often as part of their considerations of audience targeting and measuring success, as will be seen later on.

Tempering the messages of duty, the other most common theme in the responses was one of personal enjoyment of taking part in outreach. Jonas describes his motivation for getting involved in any outreach activity as "because of my CV and then also because it's kind of fun", showing personal gain alongside enjoyment, something echoed in this thought from Mike:

> I approach this I suppose personally in a rather selfish way, if I am honest. I enjoy it which tells you that I get something positive out of it for myself.
>
> (Mike)

The "something positive" Mike mentions is less tangible than the direct benefit of improved CV content expressed by Jonas, but enjoyment is an important factor for many of the participating physicists when deciding whether to get involved in an activity or not. Rob describes how taking part in outreach can be a relief from his day-to-day work:

> I would encourage everyone to do outreach. When you have a down day, a down week or a down month you just want to get enthusiastic about science again. Then you can go back to your computer and you are still staring at the same code or the same problem that you don't know how to solve but you have just spoken to a nine year old who wants to know what a black hole tastes like … I just love it because of the enthusiasm and it makes me feel like a kid again.
>
> (Rob)

The day-to-day work of a physicist, as for many academics, can be isolated and include a variety of pressures. Rob takes pleasure in his interactions with the audiences he sees, in this case primary children, and uses their enthusiasm for his presentation as a way to raise his own enthusiasm for his work.

Having established their drivers for getting involved, some went on to explain why they chose these specific activities to get involved with, commonly coming back to a request made by another academic, a school or an outreach officer. All of the participants had been involved in outreach before the sessions I observed, and for many taking part is a regular activity. For Vicente, outreach has become part of his working routine:

> And we basically do it in rotation so there is no specific reason why I chose today rather than other days. It's just something I do routinely together with my other colleagues and we just rotate these talks to students.
>
> (Vicente)

Whilst all of the participants considered outreach to be something they would do often, it was most often described as something opportunistic rather than the routine that Vicente described. Departmental programmes like the one Vicente mentioned provide authorisation for taking part in an activity, but can subdue the sense of enjoyment. Vicente uses the structured outreach programme as a way to help him prioritise taking part, as a way to choose an individual activity to take part in rather than being the driver behind his choice to do outreach at all:

> I like actually doing outreach activities although this is on top of many other things that each of us has to do. And so it's one more thing in the to-do list. But I love doing that. So I sort of use [the local outreach programme] as a chance to keep doing that rather than putting it down the list of priorities and just getting to that, well never, basically.
>
> (Vicente)

Such support for taking part, or authorisation of an individual's activity, can be important, particularly when weighing up participation in an activity against the other pulls on one's time. Even in departments where staff are encouraged to take part in outreach and engagement activities it can be difficult to prioritise outreach over other activities. Jonathan is Director of Outreach for his department, and enjoys getting involved, but research and teaching must still be considered first:

> No, it is not a priority. That is an important statement. I do it but it is not a priority. So the practical thing is that any academic has got to balance many calls on their time; so the priorities like this go as following: there is research, there is teaching, and then I will put outreach and then I will put administration last.
>
> (Jonathan)

Given the order of the priorities as listed by Jonathan, we might expect him to concentrate his outreach activity on those audiences that his department might have most to gain from. He instead presented a different perspective on outreach, seeking to reach new audiences that otherwise would not have as much access to information about physics:

> And that schools are anyway places of learning and so on and so forth; so you are not outreaching much, in the sense that whilst your outreaching to the University but not to people not in education … is meant to therefore get a non-traditional audience. And then we try and advertise in non-traditional places.
>
> (Jonathan)

Each physicist taking part in outreach activities will have prioritised that particular event over other obligations. Jonathan has a passion for reaching alternative audiences, and so that is where he focuses his efforts. Wil works towards departmental recruitment targets, within regional and national frameworks of practice, but questions how the audiences are selected:

> Yes, so I think a lot of universities get it a little bit wrong in that they tend to concentrate on A-level students because they think 'Oh we do an event and then we see two or three more A-level students from that event came to us'. And it makes it nice and easy for them to track and they pay attention to that.
>
> But particularly in physics we know that the issues happen lower down. So we perhaps shouldn't be surprised with our gender balance say in physics because it is kind of about the same as it is at A-level or well not a million miles away so it is actually before A-level that a lot of the problems are.
>
> I think people are starting to realise from the outreach point of view and certainly as part of my job I am very aware that we should be doing stuff lower down but I am not sure if universities have necessarily got that plan yet.
>
> (Wil)

Wil is in a position where he needs to respond to local drivers to justify his role, yet feels that to be most effective for the greater good he could be prioritising other audiences. Such tension will affect his enjoyment of outreach activities; as an Outreach Officer Wil will continue to deliver against the targets he is set but might try to influence the local agenda, but for an academic taking part in outreach in a voluntary capacity, choice over which audiences to work with can make a difference to their participation and enjoyment of the activity, as we will see in section 6.3.5.

Overall, whilst there are many other pulls on their time, somehow the physicists in my sample found time for outreach. Apart from Wil, whose job role is focussed on the development and delivery of outreach programmes, a mixture of enjoyment, personal gains and fulfilment of duty empowers them to get involved in outreach activities, even though it is not always easy:

> No exactly, that is what I mean. I grumble about it all the time and say, "I have got to do that outreach." But I really do enjoy it. It gets me out, and you do something different. It keeps you practised at presentations.
>
> (Alice)

This statement from Alice sums up the overall feeling from these physicists. There are enough reasons to get involved to help them overcome any barriers to their involvement. Even Wil, whose job is outreach, is driven by a mixture of duty and enjoyment. These factors can then be considered to contribute to the processes that help create successful outreach or to be some of the measures by which the presenters deem outreach to be successful. As the responses above from Wil and Jonathan imply, there are other performance indicators that the participants know they might be expected to meet, even if they are not their own personal markers of success. This poses issues for anyone participating in outreach; unless there is alignment between external, departmental, institutional and personal measures of success, then outreach activity will remain an activity that is both expected but not necessarily rewarded within HEIs, as Bill indicates:

> I am a little worried that while outreach, public engagement or impact in general is climbing up the agenda it is not climbing up the agenda in promotions and hiring. I think we could be in a strange situation where we all accept it is important, we see it is important and we see the agenda of why it is important but that then is not structural.

(Bill)

I embarked on this study with the aim of improving our understanding of outreach to help address some of the structural issues Bill mentions, and to better recognise what successful outreach really looks like. In the following section I examine the ingredients that contribute to successful outreach, before going on to look at how success is measured by those involved.

6.3 What makes outreach successful?

I have previously established that the participants in this qualitative phase of the study are predisposed towards taking part in outreach, but my request for participants did not require any assertion of quality of delivery. Any such assertion would be difficult to validate; as mentioned in chapter 3 evaluation of outreach is not consistent, and as with any activity that is not a core part of someone's workload it is difficult, and sometimes damaging, to enforce reporting requirements. To support those physicists taking part in outreach in ensuring they are following good practice some steer is needed as to what might be considered to be 'good' outreach, and I am interested in establishing this from the viewpoint of the physicists taking part. When considering their practice, the participants talked about the structures and processes that contribute to good outreach, with themes emerging around practical issues such as format and content, as might be expected, but also the stakeholders in an outreach event, including their institutions. To start I shall return to the core of my research question, and consider the nature of the presenter.

6.3.1 Presenter

> Oh yes, I think it is very important. I would probably caution that not every physicist necessarily needs to be going out talking to the public. In fact in some cases that might be harmful just because people's strengths lie in different areas but I think scientists should realise that primarily they are publicly funded and therefore the public deserves to, it is almost their duty to let people know … But I think forcing people to do it is tough.
>
> (Wil)

In the response above I had just asked Wil whether he felt it was important that physicists take part in outreach activities. He, like several of the others, does consider outreach to be something that is important for physicists to take part in but he adds notes of caution; outreach is not for everyone. This might be based on an individual's own skill set, as echoed by Jonathan:

> No. I will clarify that. Outreach is not something which is suitable for everyone. And one of the issues in encouraging people to do outreach is to really ask the question, is that person suitable for outreach?
>
> (Jonathan)

No-one went on to describe the qualities that would make an individual unsuitable for outreach or even to describe what would make someone suited to outreach, although there are elements of this within the considerations of format, content and crafting of outreach later on in this chapter. Wil's statement also comes back to the nature of selecting someone for outreach, pertinent to his work as an outreach officer where not only will he deliver but he will also encourage others to do so. Assuming he has determined that a person is 'suitable', they may not be interested, or in a position to take up the activity. In these situations, as he suggests, pushing someone into an activity could have negative repercussions for all concerned.

Not all consequences are negative; those who are enthusiastic are more likely to perceive positive outcomes from their activity:

> And so there is a bit of friendship and a bit of collegiality I suppose running through the veins of this thing. But also, you know, because I love talking to people and getting enthused about science and physics in particular, he knew

> he was pushing on an open door. So even though I am not an expert in chaos theory, I would never claim to be an expert in chaos theory; I know enough physics that I can ask certain appropriate questions of the literature or of the articles that are out there. And perhaps stay half a step ahead of the school students that we talked to.
>
> (Mike)

It can be seen in Mike's response, and later considerations of outreach development, that in presenting outreach it is often required that a presenter move beyond their own niche of research but, as Mike acknowledges, this requires some preparation work. Mike considers himself to be suitable to deliver in a research area that is separate from his own, given some background reading on the content. Each of the participants could be considered to have asserted their suitability as a presenter through the act of taking on the activity; they acknowledge though that there are steps that must be taken for them to improve their practice.

6.3.2 Developing activities, developing presenters

Mike suggests above that as an enthusiastic presenter he can turn his hand to a range of content. In the following response Jonathan describes the process of putting together his lecture on the centenary of general relativity:

> It was a lot of work actually. I basically bought every book there was on the history and philosophy of the development of relativity and read them over Christmas; and that was good. The point being is you do the talk once, you don't just do it once you do it again. So I will be doing the same talk at the IOP and a few other places.
>
> (Jonathan)

Jonathan is a string theorist; whilst the topic of general relativity is intrinsic to his own research area much of the content, in this case historical fact, is not. As an enthusiast he makes time to learn what is needed, as Mike also described previously. They both recognise that this is not enough to make a perfect presentation, as Jonathan goes on to discuss:

> So I said, there is an interest in performance points of view, when you teach that is a performance effectively. It is a pedagogical performance and part of

> that is if you can do it at the lowest level possible that feeds into teaching. And the same I would say is also true, even in a research level where if you go to conferences and you go to seminars then at a research level, again the sort of practice performance which is something that can be honed at a higher level in outreach activities, feeds into that. So, there are not quite as independent as you first may think.
>
> (Jonathan)

The nature of outreach and giving talks, or performing as Jonathan puts it, is that improvements can be made through not only preparation but also practice. The cycle of improvement felt across outreach and talks as part of research and teaching that Jonathan describes could be considered to be one of the benefits that help to motivate researchers to get involved. Such improvements can be made through reflection and revision for the future:

> There were a couple of moments when I thought "okay, I should improve that". Probably, the last part of the talk, after they had the experimental activity, was a bit of an anti-climax. Probably, I should have thought of something that would finish with that activity, and then just wrap it up, rather than adding new information.
>
> (Marina)

Or changes may need to be made once the activity is already in progress:

> Every audience is slightly different. Like today you could probably see my slides were at a rather more advanced level than the audience. I realised that I couldn't just read the slides, I had to explain the slides for the audience. Which means I had to cut through most of the technical stuff to get to the nuggets of information so that it would be accessible to them. Hopefully that achieved, I think they probably got most of what I was saying.
>
> (Bill)

A good performance involves the use of many skills, and the ability to react to changes in the environment within which it is delivered, whether it is for outreach or teaching, or presenting at a conference. Marina and Bill are considering the needs of their audience as they make these changes, both on the day and in post-event analysis. Such considerations are a form of evaluation, and are influenced by personal and institutional drivers such as those expressed by Wil in section 6.2, and by Alexander:

> So I like to think about what I'm trying to achieve, why and how have I targeted that audience? One reason to do this is to grow the physics pie, to enthuse and grow interest in as many people as possible. Increase the number of people that are involved in physics in some way. It's also to do with recruitment, so if I'm working with A-level students, that's about us getting a bigger slice of that physics pie, helping Industrial to have A-level physics students come onto their degree course.
>
> (Alexander)

Whilst Alexander cites the building of a more scientifically literate public as his motivator elsewhere, here he shows how his development of outreach activities can be driven by institutional drivers. His major concern is the impact of the activity on the audience, in this case students that might be recruited to his institution. He goes on to consider how he enables his audience to engage:

> It is important to provide the space to ask questions and to overcome cultural barriers. In the UK it's okay, many people will feel they can ask questions but even still I have to put effort into making sure they know that I welcome them. In other countries – I've worked in Switzerland – the culture is not to ask questions and that is a little bit confusing as a speaker. I've never had any training in this so I guess this is instinctive, but I do try my best to make sure they feel they can ask questions in the right time.
>
> (Alexander)

Alexander makes efforts to enable his audience to ask questions. He talks about an 'instinctive' process; one he has not been trained in, but that he feels is important. His value of this process includes valuing the intrinsic qualities he must have to be able to use it, something also apparent in Bill's description of how he amends his presentations in the moment, above.

Personal performance is one aspect of improving audience experience, but as Marina mentions above, altering a performance to the needs of the audience might include content or format changes, use of different audio-visual materials or demonstrations, or improvements of a technical nature:

> I think that because our dome is four years old it is looking a bit tired. I think if we had the money to upgrade the projector technology and the computer technology. To make it more high definition, more interactive, and if we had the money to make the shows more immersive because Stellarium is pixelated at the resolution we can run it. I think it would be more successful if little things were tweaked and improved.

(Rob)

In this statement Rob is concerned about the look and feel of the activity and audience experience, wanting to present the best possible image to those he interacts with. The 'dome' he refers to in the quote is a mobile planetarium, a highly technical and very professional looking set-up. As he discusses the technical limitations of the equipment he is using he refers to making the shows more 'immersive', a term used to describe participant interaction with a variety of digital environments and the suspension of disbelief that they might experience through these interactions. Rob has used this particular format for outreach many times, and trusts the equipment to immerse his audience in their experience, so his focus for improving future sessions is on the technical aspects rather than his own role as presenter.

In considering the skills involved for the physicists taking part in outreach, whether they are around presentation, reacting to an audience, or technical, it is also important to consider where these skills come from. Rob has had extensive 'on-the-job' training in using the planetarium equipment; one of the benefits of the show always needing at least two members of staff is that there is an opportunity for shadowing an experienced presenter. Not all outreach comes with such a framework for support. A higher education teaching qualification is prerequisite at most HEIs now, but being ready for teaching in a higher education context does not necessarily prepare someone for the range of audiences and environments involved in outreach activities. When considering doing outreach as an individual, as part of a wider programme but without a set delivery formula such as the planetarium provides, more support is needed:

> [Particle physics is] a complex subject. There are other subjects, which are a bit closer to everyday perception of the people. And I think there is a huge room for improvement. We don't usually get any training. I didn't get any training to do outreach activities. And I think one really should get some training for that because it's really different than anything else that you do in your work.

(Vicente)

Vicente sums up the feelings of all of the participants in my study in his final sentence. Outreach is an activity that requires skill and thought, an activity that is complementary to but different from the core tasks of an academic.

6.3.3 Content

In the conversations so far there has been regular mention of what someone delivering an outreach activity might do with their content. Now I go on to look at what drives that content and how topics and elements of a presentation are chosen. A lot of outreach includes elements that are designed to make their audience go 'wow', as Jonas explains:

> Yes. When you show them how big the universe really is, they are kind of amazed and you can talk about supernova, black holes, which are really exciting things. It's words that people kind of know from before and then once they get it explained, I think they find it cool. I like to think that.
>
> (Jonas)

Jonas wants his audience to find his topic inspiring, and leans on his own excitement to inspire him in choosing what to include. For Jonas this means extremes of size, aesthetically pleasing phenomena and those phrases that have been picked up already in popular culture, like black holes. For Rob, this wow-factor is particularly important for schools audiences:

> Yes, schools want to be visually blown away. They want to have a look at something and go, "Oh man that is cool". Whereas I think when you do general public and you have parents or middle-aged people they are more interested in the details. It would be enough I think if I was to do a primary school show in the dome just to do a slideshow of pictures and the kids will go, "Wow, what is that?". But some adults will want to know, "What technology did you use to capture that? How difficult was it? What steps go from taking a picture to making it look like that?". You do have to tailor your show to impress or satisfy your audience based on their age and interests.
>
> (Rob)

Although he started out by suggesting that younger audiences are more impressed by compelling images than are older audiences, Rob goes on to describe the difference between the audience responses to such imagery. Rather than concluding that a different approach is needed in the content, what seems to be important here is the ability of the presenter to react to questions knowledgably and adding detail and process to the content being discussed.

Inspiration and excitement do not have to come from the topics covered, however, as Mike explains:

> The classic areas where school students are supposed to go wild is when you talk to them about space things or the Higgs boson or whatever; big ticket things that have been in the press. Actually what I have discovered that given a few minutes of their ear time you can actually get across enthusiasm for a very wide range of things.

(Mike)

Mike and Jonas both come to their outreach content from the point of view of passing on enthusiasm for science, sentiments echoed by most of the participants. Yet they disagree on what content is helpful for them in doing this. In both cases there must be some kind of 'hook' for the audience, something to enable them to engage with the rest of the talk. What Mike suggests here is that whilst the wow-factor can be a hook for the audience, it is possible to be compelling even in those areas that do not have such pervasive or remarkable phenomena.

Whilst content such as the size of the Universe or black holes can grip an audience, or an excellent speaker can win them over with their own enthusiasm, others might take a more pragmatic approach, such as Marina:

> Because, medical physics is something people have heard about, and they see the real life application for it. There are a few things that can be hands on activities, and people see the immediate utility of it.

(Marina)

Showing the applications of science can provide a way of building understanding with the audience through concepts or practical uses that they are familiar with. As Marina highlights, some areas also lend themselves to practical activities for the audience to do themselves as well as listening to a speaker; this can help the audience to see the purpose of the research being presented.

Discussing the applications of science also opens up discussions of careers in science, which can be important to the audience if they are at a decision-making stage of their lives:

> I think it's really useful for the students because at that age, we are all confused. We don't know what we want to do later and you need to use informal environments where there is lots of information and it helps you to decide how to go forward.
>
> (Armin)

For those presenters responding to institutional or external recruitment drivers such messaging can be important in winning the hearts and minds of the audience. Inclusion of the wider impacts of research is a way of helping the presenters to respond to other motivators for involvement, such as the burden of duty expressed in section 6.2, helping the audience to understand what benefits they receive as a result of funding. Even applied physics research is linked to research that is highly theoretical, however, and most researchers are not driven by a desire to produce immediate applications. This can cause a tension for some presenters in balancing their content:

> We always try to keep it two sides and discuss the spin-offs, basically, what we do, like internet and medical applications and these sort of things. But that's not what we do, right. That's just a side effect. The point is that what we do, we believe that what we do is relevant, not maybe to improve our life tomorrow, but to improve mankind as a whole, to bring the frontier forward.
>
> (Vicente)

Vicente is a particle physicist. Whilst there are well-known impacts of particle physics on everyday life, such as the development of the internet, it can be difficult for current researchers who feel they have to justify the details of their particular area of research to the public. Such research may well have practical or easily accessible impacts in the future, but not lend itself to a discussion of such outcomes at this time. Here, Vicente also considers the issues of focussing outreach on the direct impacts of science research. For many physicists the impacts of their research may not be felt by the public until much further in the future, if at all. As Vicente says, physics research is generally undertaken in the pursuit of knowledge and improving our understanding of the world, rather than to produce applications.

The issues of demonstrating impact are particularly pertinent for astronomers and cosmologists. Alexander finds other ways of making his research relevant to his audiences:

> I like to use recent or current news stories to make an event or some content easy for the audience to understand, and to make it relevant to what they might do at home. For example, just recently there is the space vegetable story. When I spoke to the four-year-olds this morning I told them about space salad. Hopefully they'll go home and remember, when they're talking to their mum about their dinner, about space salad. A little bit of this is about humanising science. It's seen as a distant, wizardy thing, so what I need to do is to try and undo the insecurities people have about science and being part of it. We have to cut through prejudice, the prejudice against science.
>
> (Alexander)

Alexander describes this inclusion of relevant news stories as "humanising" science. This concept can be seen in Jonathan's curating of the history of general relativity, Wil's use of familiar images as shown in the previous chapter, Marina's use of a practical demonstration and in the various attempts to demonstrate the impacts of research and researchers.

These considerations of content are focussed on the audience needs or desires, which include a mixture of education and entertainment requirements. Yet for outreach targeted at school groups or other organised parties there are two distinct 'customers': the visiting group, often young people or schoolchildren, and the group organiser, often a teacher or someone with another educational duty of care. Despite my encouragement of all the participating physicists to look at their activities from both of these perspectives they almost always considered them as one audience, assuming that if the student group were happy with a session then the group organiser would be too. Where teachers were mentioned, they were acknowledged as a recipient of the outreach content, as described here by Alice:

> Science teachers don't know everything and what you can bring is new research that is upcoming, stuff the teachers don't know about. I mentioned the Rosetta mission which is all happening at the moment, which I think is brilliant. I think again the teachers might not know about and if that gets them Googling stuff then brilliant.
>
> (Alice)

The situation Alice describes fits the deficit model of science communication, in that she perceives herself to have information that the audience, in this case the teacher, would benefit from. Taking a different perspective, Mike related his understanding of

the needs of the teacher to the ways in which they might judge outreach to be successful:

> So they are going to be measuring this also in terms of, "Did this make my class easier to deal with when we did our next science project? Did it cover something in a way that's going to strengthen or amplify or underline what I have done or will do?". And those are perfectly reasonable questions.
>
> (Mike)

Mike has shown an awareness of how the teacher might want to build an outreach activity into their classroom practice and connect it to the content they are teaching. Building such a specific set of requirements into an activity requires thought and an understanding of this particular audience's needs, which I will come back to in section 6.2.4.

6.3.4 Format

When Alexander talks about 'humanising' his content, he considers the ways in which he tells a story to his audience. Marina thinks about the way in which she can demonstrate the phenomenon she is describing. In both these cases the format of the activity is important as well as the content. The outreach activities I saw all involved talks, albeit in different environments and including different usage of technology and props, and most of these were in a traditional lecture style even when not in a traditional lecture space:

> I like being in control, I like answering questions and I like passing on knowledge. I think that is a really good way to do it, especially if you can put videos in there and if you can get a question and answer going. I know that didn't really work today because they were a bit quiet but it never does. I try, in earnest. I like that style because I am confident in that style of lecturing and I think my enthusiasm comes across, so that is why I choose to do it that way.
>
> (Alice)

For Alice, lecturing is a familiar activity, and allows her control. Whilst the term lecture conjures up the image of an audience limited to sitting and listening, this is not the desired outcome for most of the presenters. All of the sessions had an opportunity for questions at the end, some allowed them earlier. Marina delivered her session in a lab,

and so broke out of the lecture style for some minutes to allow the students attending to have a hands-on experience, before going back to the talk. Even within the talks there can be opportunities for the audience to be less passive, as Jonas describes:

> From the undergrad [outreach] in Denmark we did a lot of evaluations and from the evaluations you could tell that there was a 100% scatter. Some students wanted to have more theoretical, more equations, some wanted less equations, some wanted more of me talking, some wanted more activities for themselves. It really depends a lot on this. I think, for me, it's nicer to have both, a talk and a set of exercises, because some people find it much more interesting to sit around and fiddle with some small exercises they can do and other people find it nice to just sit and listen and take in what I'm saying. If you have both, then at least you hit all of them, I think. Now there could be some who want to just have a bit more exercise and time to noodle, to learn a bit with pen and paper.
>
> (Jonas)

Although his own contribution to the outreach session I observed was a pure talk, with no opportunities for the students to do exercises of their own, Jonas appears to understand that different people engage or learn in different ways. How these different elements of engaging the audience are employed might depend on your main motivation for being involved, as in Alexander's case:

> Some of this is about building a community, either outside of the university or even within in, because there are many people here who are not physicists and want to know why the university is spending, for example, £50,000 on a new observatory on the hill. Those stargazing events are for people from age 5 to 105, so targeting is difficult, it's a broad audience. It's family-oriented, the level is basic, but there is the opportunity to meet real scientists and ask genuine questions.
>
> (Alexander)

The session Alexander refers to was held outside, next to the observatory being opened. Whilst the main content was a talk from Alexander, the intention had been to include live group observation on the big screen, followed by the chance to use smaller telescopes with researchers, and look inside the observatory. The live observation did not work due to weather conditions, but the public did stay for a considerable time after the talk to look around and explore the equipment of astronomy, whilst talking to the local experts. His desire to include the public in the use of the observatory as the

programmes around it develop can only be met if members of the public are invited into the spaces, and given the chance to interact with the scientists involved.

6.3.5 Supporting roles

The event Alexander is talking about above included him as a main speaker, but also involved an outreach officer, a team of student ambassadors, other physicists and the local amateur astronomy organisation. Each had an important part to play in the event being successful. Alexander describes the supportive culture that enables this to happen:

> We're actually very lucky in Industrial that outreach is very well supported. We have an Outreach Officer, we have [a Professor of Public Engagement in Science], there is a culture here of doing outreach. But there's a huge barrier to many, particularly in other institutions I've worked at where outreach isn't considered as part of the tenure programme. So it's good that you're doing the outreach, the department wants you do it and is pleased that outreach is happening, but in no way are you rewarded for the work that you've done.
>
> (Alexander)

At Industrial then we know the physics department has support structures for outreach, such as the dedicated offer role, and also leadership through the awarding of a professorship in this area. Such a culture is likely to have grown organically, from the work of interested parties such as the Professor mentioned above, or those in this extract from Wil:

> In our research group I think it just so happened that a couple of our professors were quite keen on this sort of work … And I think the drive for a lot of the stuff still came from myself and my other colleagues and PhD students. But certainly there was a lot more acceptance maybe in the nanoscience Department. There were some of the groups who didn't do anything and would look unfavourably on their students, wasting their time as it were by doing such a thing, so, that would certainly have an effect I guess.
>
> (Wil)

Personal drive to get involved is a significant factor, but support from those people in charge of you, such as line managers or supervisors, can make a considerable difference. Wil has developed his career from a research group which supported his outreach work, even if other groups in the same department were less approving. Where

support from managers cannot be guaranteed, the alternative is for individuals to go without seeking approval:

> I will go off and do something in my own time without the department's help if someone has asked me to. I haven't actually asked my line manager if I could go today, I just went.
>
> (Alice)

Alice is a post-doctoral researcher, so might be considered to have slightly more professional autonomy than a PhD student and not need to ask permission to take part. Her department is supportive of outreach, so even without direct manager support she has a structure to rely on.

Manager and management support is more than just approval to take part. Visible leadership can encourage others to get involved or provide role models of practice. A culture of getting involved in outreach includes rewarding those taking part in outreach activities, and eventually providing full recognition for this work as a core part of an academic workload:

> I just think that it is important to educate the senior management such that when they sit there and they judge this multifaceted person they have to see that outreach is as important as publications.
>
> (Bill)

Bill, as a Head of Department, is in a position to make the sorts of changes that enable staff and students in his department to build their outreach activities into their workload, but that does not mean that they will find it is recognised in promotions criteria. Whilst a group, or even departmental, culture of outreach can be a positive environment if it is not linked to institutional processes and procedures then tensions can develop.

Some of the departmental or institutional support for outreach is shown through the provision of staff to support outreach activities, including leadership roles such as Directors of Outreach, recognition roles such as professorships, and professional roles such as Outreach Officers. This last role comes up in all of the conversations as a critical point of supporting successful outreach, primarily for the logistical support they provide:

> You may know that our Outreach Officer at the time you came to visit, Kate, has moved to the Institute of Physics, and we haven't been able to replace her yet because we've been trying to work out what to do with her post. In the interim we've had to cut down our programming and the work that we have done. We've met all our commitments but we haven't taken on any new activity in this time, and that's a real shame. We need that post in place because she really helped us get the most from what we could do in our time.
>
> (Alexander)

The Outreach Officer provides relief from the administrative burden of outreach, but can also provide focus and thought about how best to target programmes of activity:

> Without that what we have is a whole bunch of part-time amateurs like me, who can scrape together the odd afternoon occasionally, but it is never going to be a coherent approach to schools' outreach. It is never going to be focussed in the sense that Linda, the person who does this for us now, is able to do.
>
> (Mike)

For most of the participants the outreach officer role, by virtue of being a dedicated professional post typically held by someone with a strong academic background or practical experience in physics, provides a conduit for sharing ideas and developing content. Outreach Officers have the capacity to make links that the academics do not have time for. In most cases they are considered to be someone from whom to get advice and feedback when developing and reviewing programmes. There can be a tension when considering them as expert roles, and as is shown here by Jonathan, a tension in the perception of 'professional' roles:

> Well I should add so here I have got a role which is that I am Outreach Director and I believe that is almost unique in the sense that we have an Academic Outreach Director that liaises with them … And the point being is that it brings a closer involvement between the staff, I mean as in the academic staff and the Outreach Officer who do other things. Because the danger can be is that the Outreach Officer doesn't know who even the staff are or what they do or their capabilities or what sort of things were available. And having them embedded in the Department means they get to know the academics much closer.
>
> And then there is another bit to that which is that they can take on other pseudo-academic roles and what I mean by that is, by being here and working with academics, they can see things for example like grant opportunities or they can tie things like for example 100 years of GR because they are in a physics department where we are getting emails from STFC about 100 years

> blah de blah. So there is a much closer working relationship which allows all of these opportunities to come forth.
>
> (Jonathan)

Jonathan's academic role of Outreach Director is by no means unique, but the fact that he believes it is suggests that he has not yet met others in similar roles. Jonathan is appreciative though of the capacity the officer role can bring to taking up external opportunities, applying for funds and participating in national programmes as part of what he describes as 'pseudo-academic' tasks. Such capacity ensures limited resources are well used; it can be tempting for colleagues to consider the officer as a way of them no longer needing to take part in outreach activities:

> The key thing that we are conscious about at the time and we tell people all the time is that Jo is not there to do the outreach. Jo is there to coordinate, help, facilitate and encourage. Not to walk in to my office and I say, "There is a talk you have to give Jo". I think that is very important, also then, seeing how we build a career path for someone like Jo.
>
> (Bill)

Bill describes Jo, the outreach officer, as being there to 'facilitate and encourage'. Mike explains that such work requires specialist knowledge and abilities:

> The big step for us and this is where the link with schools comes in, I think very explicitly is that it dawned on me and on others very, very quickly that we needed not to have an academic running this show, but to have someone who quite explicitly spoke the language of the school.
>
> (Mike)

The skills involved in this work are beyond delivery; the officer is expected to build a community of outreach within their department, and such a community can have unexpected benefits. Rob chose to do his PhD at City because of his experiences in outreach:

> My supervisor is very accommodating. He doesn't want us to do these trips too often because that is days off of our research, but he is more than happy for his students to go and do these events. I think also it is good for social bonding within the group. I know that when I was an undergrad and I joined the astrodome I was very shy. I was in my second year and I was a very shy person. Jenny introduced me to the PhDs and if we'd had a long day doing a dome she would say, "Do you want to go to the pub afterwards?". She would round up the other PhDs and it was nice just to hang out with people.

(Rob)

It can be easy to think an Outreach Officer's role is one of delivery. What these statements show is that there is inherent emotional labour involved in such a role, as well as a need for expertise in development and delivery.

6.3.6 Audience

In the considerations throughout this chapter the audience, and their reaction to an activity, have been mentioned as a way of measuring the success of outreach, and I will come back to this later on in the chapter. Here I consider the role of the audience in making outreach a success. Alice considers how she chooses an audience to work with:

> From a personal point of view, I don't like giving talks to people who don't want to be there because they are disruptive and this is the reason I am not a teacher. If they want to be there they are already switched on, which means they are going to be attentive. If I can then ignite that a little bit more and say, "Yes, this is as fun as you think it is. This is as exciting". Then that is great … I think if you have people who want to be there then they want to learn and they are attentive.

(Alice)

There is a fundamental point here about audience choice. Where the audience has made a conscious decision to take part in an activity it makes a difference to the presenter; the audience behaviours and attitude are affected. Armin extends this point of view beyond choice to the way in which a group is organised to attend:

> Well, it depends. If I want them to be quiet, then [pause]. If I'm trying to engage and I don't get anything back, I guess it's disengaging. It's also the way it's been organised. You could organise an event that they want to come, they have been sent to come from something, they will pay more attention to it rather than being forced to go somewhere. So yes, it's also how you ask them to be there.

(Armin)

In the case of school activities it is rare that the students are given a choice to attend. Such a decision will lie with a teacher. Armin suggests here that tailoring the content,

and the ways in which such a group is welcomed or informed pre-event, can give the illusion of choice and so improve the audience experience.

It is not just the audience experience that improves when the audience have more ownership of their role in the event. Here Vicente describes his experience in being invited to a school by a group of students:

> Well, I went to some place in Kent. I don't know exactly what place in Kent. It was a high school. It was really nice. I was invited first. So it was not students. It was a group of students fond of science. They were very young. I think it was early on in their career. But they went to the Campus website. They invited me because we have a list of seminars that we give, usually. And that was extremely successful. It was even a bit more complicated than that, a little bit. Just a little bit. And the reaction was wonderful. I mean, we had a whole lot of discussion at the end.
>
> (Vicente)

The students involved in this experience were in charge of their own programme of speakers, and directly invited Vicente to speak. It is likely that they were already enthusiastic about the topic he could bring to them, and were prepared to do some preparation of their own. The other extreme of this phenomenon is described by Rob:

> From a selfish point of view, yes. I always prefer to do the primary schools because I prefer their enthusiasm. I think when the kids hit their teenage years that can be tough because they don't want to engage with you. They know their teachers force them to be in the dome. By that age they have probably decided they don't like science, whereas I think every primary school kids loves science.
>
> (Rob)

Rob describes himself as selfish here, but there is a consideration of the audience experience inherent to his dislike of forcing groups into the activity that justifies his concern beyond self-interest. All stakeholders will have a better experience if some element of freedom to attend is present, and this poses a particular issue for schools outreach.

6.4 How do you measure success?

So far I have considered the factors that influence outreach delivery, in places touching on what it means to deliver good outreach. If outreach is to continue to be a key activity area for physics departments then developing a better understanding of the outcomes of outreach is essential:

> In terms of public engagement for REF I hope that we get a very strong steer and a very strong feedback on what is good practice. They now had a tremendous amount of input. They have judged it, they have judged what is good and they have judged what is bad. They really need to tell us what is good.

(Bill)

Bill highlights the 2014 REF exercise as a potential way of good practice being shared throughout the community, moving towards a shared understanding of what good public engagement or outreach looks like. The REF impact statements, whilst public, are not directly linked to the scores they received so we do not know exactly what was considered to be good practice in this exercise.

6.4.1 Capturing data

The major issue with evaluation throughout the physicist responses appeared to be one of expectation; evaluation forms were felt to be an expected part of outreach, yet it was not obvious how they would help the physicists to measure the effectiveness of their activity. An example is Wil, who set out his goals for the lecture I attended:

> That physics is more, how should I put this?; it is more approachable almost, it is not that it is for super brainy people like Brian Cox who gets to stand up and talk.

(Wil)

Wil's aim for the event was for the audience to go away with a particular perception of physics, but when he talks about measuring successful outreach later on he falls back on tracking whether the audience might go on to become physicists or not. Whilst the lecture was mainly full of schools groups there were also other members of the public

and university staff in attendance, so it is unlikely that those audience members would consider starting a career in physics:

> So what makes successful outreach can sort of differ. This talk was meant to be an interesting talk in the evening, so people have done that, it was successful. On that extent I probably won't know if it is successful until I could sort of go back and ask every student in six months' time whether or not they remembered it and whether or not they were now going to be physicists. I think tracking it is still a hard thing to do. I am not sure everyone's really cracked it yet.
>
> (Wil)

In this instance tracking is made possible through the guest list; as the event was ticketed Wil can contact those who booked the places. Yet for school groups, who are likely to have been booked by member of staff as a group, this means that he has the contact details for the attending teachers, not the students, so the likelihood of being able to follow up with those who attended is low. Rather than Wil not having understood this, it is more likely that this divorce between his action and intention is another indicator of tension in his role between meeting institutional goals and his own drivers for being involved.

Where evaluation is concerned there is no single way to capture data. Alexander expresses here the importance of changing evaluation tactics based on the audience:

> It's important to evaluate, find out how it went. Did it succeed against my goals? I use forms for this, or I ask questions if, as in the case of the session this morning, the young people are too young to actually complete a form by themselves. In that case I'll check in with the nursery school leader to ask whether she felt the event was worth doing and would she like to do it again, and what would she change if she did it?
>
> (Alexander)

Here he is talking about another outreach activity he did just before the interview, talking to the on campus nursery about physics. His questions for the nursery leader are formative; he will use this information to help him decide whether or not to do that activity again in that way, based on the nursery leader's understanding of how the activity has been for the children. Even here, when amending the style of questioning for a given situation, there are problems in collecting useful data. A post-event conversation is unlikely to be recorded, so cannot be shared easily with others except

through anecdote. Use of forms can collect a large amount of information, but not always be compiled into one dataset or analysed. There can be pitfalls where the collection of data concerned, as described by Mike:

> I will show you our global figures, I will show you that there is a positive correlation between the innovative and energetic people that have been involved in outreach from this department and our bulk numbers of student recruitment. And as I say, it has gone way beyond anything that you could class as a national subject average. And I would contend that that positive correlation speaks volumes, irrespective of the explicit points in the memory of students. But it is also nice to hear the anecdotal tales. It is an illustration of what we would observe I think in terms of just statistical correlation.
>
> (Mike)

Mike can demonstrate correlation in his data, in this case showing increased recruitment when an effective outreach role is in place, but he cannot demonstrate the causality of outreach on student choice. He alludes to issues in collecting the students' memories of outreach they have experienced, where often they do not recall a specific incident, or relate it to their decision making process. Whilst the data that can be easily collected are audience numbers, the 'anecdotal tales' can provide a deeper insight as Mike suggests, which requires an understanding of qualitative collection and analysis techniques. One solution to this is to bring in an external party:

> Without sitting these people down after the event and really sort of grilling them, as it were and even then they might not spill the beans. It might need a third party, someone like yourself to come in and do this.
>
> (Mike)

Mike shows here the final issue with evaluation of outreach. The presenters, and even the staff who support delivery such as outreach officers, do not always have the time or skills to thoroughly evaluate and evidence the audience outcomes of the activity they have delivered.

6.4.2 Audience response

If evaluation is not primarily around audience outcomes, then other indicators must be being used to indicate success. In section 6.3.5 I demonstrated the importance of the

audience in contributing to successful outreach, through their attitudes and behaviours. Throughout their responses the physicists who contributed to this study came back time and time again to the importance of interaction with their audiences. At a basic level, audience engagement is intrinsic to the purpose of outreach, as suggested by Alexander:

> [Outreach] activity should be a dialogue not a monologue. I constantly ask questions and hope that the way I use my language allows the audience to get involved with what I'm talking about.
>
> (Alexander)

As Alexander implies, the audience can indicate their engagement with a subject by responding in some way. The most obvious way, and by far the most often mentioned throughout the responses, is by asking questions:

> And it was just huge fun and they were so enthusiastic about what they are doing; and asking the most difficult questions because, they have no fear of saying something that is foolish, I suppose.
>
> (Mike)

Mike responds positively to the questions he is asked, in this case because of their content but also because they are asked freely. When questions are asked freely, they are seen as a marker of an audience's interest:

> Once the ice was broken the kids started to ask questions. They weren't asking questions that were fed to them by a teacher, they were asking questions that they were interested in, so that is always a success.
>
> (Rob)

Whilst such questions are asked by a small proportion of the audience, they represent to the presenter an indication of wider engagement throughout the audience. Rob also considers the role of the teacher in the students' response to his activity. Where attendance is not through choice as is the case for school visits, discussed in section 6.3.5, then expecting the audience to demonstrate their interest in the subject can be disappointing for the presenter. Vicente explains why audience response can make such a difference:

> It depends. Sometimes there's just one question that comes up while you are speaking that brings it to a slightly different direction and allows you to have more interaction and a bit more participation from the audience … It's also to

> re-engage yourself while you're speaking because, if you don't get any reaction, which sometimes happens with young students, it's a bit difficult to understand if they're following you. I mean, I could see from their faces that there was half of the classes that was … Well, a third of the classroom was almost sleeping and a third of the classroom that was listening carefully to what I was saying, but that's all the feedback I got, which is not much.
>
> (Vicente)

Eye contact and looking engaged are also mentioned in other responses, and here Vicente explains that such interaction, even though it is slight, helps to keep the speaker on track. He sums up the importance of questions in his opening sentence; just one question can allow a speaker to reframe what they are saying, and improve the audience's experience. Such an interaction cannot be planned in advance, but has the potential to radically change the success of an activity for all stakeholders.

6.5 Summary

The interviews discussed in this chapter provide insights into the purpose, structures and success of outreach from the perspective of a group of outreach-active physicists. From this perspective I have shown that there are key motivators of duty and enjoyment that drive their participation in outreach, that then go on to influence both the ways in which the physicists develop, and measure the success of, their outreach activity. Having explored in the last three chapters the perceptions of outreach by both a wide group physicists and a small select group of physicists, and my own observations of a series of outreach activities, I shall in the next chapter go on to look across these three strands to inform my understanding of how this relates to schools outreach specifically, explore the role of the Outreach Officer, and construct frameworks for skills development and success in outreach.

Chapter 7: Discussion

7.1 Introduction

Having presented three distinct groups of data in chapters 4, 5 and 6, I will in this chapter bring these findings together to provide a more complete understanding of the issues they raise. In doing so I will demonstrate the progress I have made towards answering my research question, and make recommendations for those who take part in or manage physics outreach programmes with the aim of improving these. This will all contribute to the answering of my overarching research question 'What are physicists' perceptions of outreach, and how does this impact on their participation in and delivery of outreach?', by providing an overview of the physicists' perceptions of outreach, and exploring how this affects their outreach activity.

7.2 What are the contexts within which a physicist takes part in outreach?

It is not possible from my samples to generalise as to the views of the whole population of physicists in the UK; as discussed in sections 3.2.1 and 4.2, the samples are biased, with the majority of respondents to the questionnaire indicating that they are already active or supportive of outreach and engagement activities. The observations and interviews were intentionally undertaken with physicists active in this area.

7.2.1 Definitions of outreach and public engagement, and where terminology matters

The population for this study did not see a significant difference between outreach and other public engagement activities, with most using the terms interchangeably. When specifically asked to draw a distinction between the terms, a small proportion of the respondents are clear in their understanding of outreach as activity which is more on schools, in line with departmental recruitment initiatives, but for the majority of participants, including those who took part in the observations and interviews, there is

no clear distinction. For the physicists participating in the outreach activities I observed and the interviews that followed, what emerged was a more complex understanding, with schools outreach being considered as effectively the same process as any other outreach activity. For all respondents, both public engagement and outreach were considered to include a range of science communication and dissemination type activities, such as media work, consultancy, blogging and citizen science, yet the activities I was invited to watch ended up being very similar in format and delivery, all including talks from the participating physicists; the reality of the delivery of most outreach activities is that they are predominantly disseminative.

This poses a problem where the terminology around outreach is mixed up with that of engagement. The lack of clear and widely understood and accepted definitions leaves the participating physicists in a situation where through lack of shared understanding they may take part in activities that do not yield them the reward or recognition they deserve for the efforts they put in, particularly the type of recognition that would positively influence their career. This is of particular note when we consider the external influences on decision-making processes in outreach.

7.2.2 External push vs. internal drive

> Why did I get involved in that particular one? So the point of having a series of talks that were not aimed at schools was because we were aware that in terms of REF outreach impact cases, schools are not deemed to be well thought of. It is not that people discourage people doing that but it goes more under the guise of recruitment. Mainly because there is some sort of argument, I am not saying rightly or wrongly but the impression is that if you are talking to 14 year olds, you don't do it so much about contemporary research but just about Physics as a whole.
>
> (Jonathan)

Reframing evaluation of outreach in the context of external pushes, such as the REF or access reporting for OFFA, highlights the need for more thoughtful consideration of not only the reporting of outreach outcomes, but also the ways in which physicists are encouraged to get involved with outreach and engagement activities. The 2014 REF exercise provides a good example for these issues; whilst for some areas of physics

research, outreach programmes have the potential to provide significant impact case studies, this is only possible if thorough and well evidenced evaluation of the outcomes of such work is collected, as was the case for a few successful examples. The quote from Jonathan above is, however, indicative of issues in this system; shared understanding as to what is good evidence has not been established, and many are still responding to comments on sample case studies submitted in the REF dry-runs carried out in advance of the final submissions. For staff trying to influence outreach programmes it becomes increasingly important to keep abreast of the changing influencers with HEIs if they are to support the multiplicity of perspectives that the physicists have.

7.2.3 Overcoming barriers to engagement

The survey responses reported in chapter 4 reinforce previous messages (Royal Society 2006, Ecklund et al. 2012, Davies 2013) that pressures on time are one of the biggest barriers faced by physicists when considering their participation in outreach, something which has since been re-established by *Factors affecting Public Engagement* (Burchell 2015, TNS-BMRB & PSI 2015a, b), a report commissioned by a grouping of major funders of research following up on the work previously carried out for the Royal Society. These issues were also raised in the post-activity interviews; however, here the strength of feelings of duty and enjoyment became apparent as factors which enable the physicists to find ways around any barriers they face, including pressures on time.

Tied into discussions of time pressures, concerns were raised about the lack of structural and embedded support for outreach, highlighting issues for long-term support and recognition of such work. The activities that the physicists found most rewarding were not always the ones that their institutions might consider the most important. Outreach officers add value to outreach programmes through easing the burden of logistics and other preparations, yet their roles are often tied to these same institutional agendas that cause tension for the physicists.

> I don’t know because the reason I get involved is just personal. You could call that moral, I don’t know. I don’t know really. I hadn’t thought about this. I would say my personal opinion is that I feel more energetic about it when I do

> that. When I talk about my work to others, I feel good. That I have done something and people know about what I do.
>
> (Armin)

A second issue arises when considering issues of time pressure. In an environment where workload is carefully apportioned, and targets include income, teaching outcomes and success in league tables or satisfaction surveys, it might be considered risky for an individual to look as though they have plenty of time to spare, for fear of being given additional work. From the perspective of managing a physics department, or a departmental outreach programme, it can be easy to over react to those voices we hear most strongly, or those who complain a lot. Such voices take up the majority of our time, when the quieter voices of those who are shouldering more than their fair share of a burden, or who are uncertain and needing some encouragement, can be overlooked. Whilst loud voices are important as they are heard not only by outreach managers but also by senior leaders and other policy makers, it is important that those of us managing outreach programmes do not lose sight of the quiet voices or those who are undertaking outreach without seeking attention for it. A culture of recognition for outreach can help to overcome this, but must be supported at every level from student and academic through managers and heads of department to heads of faculty and senior management.

7.2.4 Duty and enjoyment

As touched on in section 7.2.2, across the survey and case studies I found that physicist participation in outreach is underpinned by a sense of duty, as part of recruitment activity, to their institution or to the subject more widely, or to inform the public about physics research. This mirrors the findings of previous studies (Royal Society 2006, Ecklund et al. 2012, Davies 2013) that found that scientists reported that enjoyment was a motivating factor for participation; I found that this sense of enjoyment was particularly strong in my study participants, across both the survey and case studies. This enjoyment is caused by a variety of factors, depending on the perspective of the physicist; for some it reinvigorates their own interest in their subject, allowing them to take a broader perspective on physics instead of focussing only on their current research and teaching or to engage in a different type of activity to their normal work. The case

studies showed the importance of audience response to the physicists' talk or performance and this is perhaps the most important trigger of enjoyment for outreach, the gratification of reaching your audience and a job well done. These intrinsic and extrinsic drivers mirror those found in other third-space or boundary professions where there is a tension between being a performer and an educator, such as music teaching (for example, Scheib 2003 and Pellegrino 2009) which may provide useful insights for future research.

7.2.5 Roles within outreach delivery

In exploring the nature of outreach delivery, some practical considerations emerge. A variety of different roles are played out by the physicists and outreach officers involved in any outreach activity and, where schools are the audience, by the teacher too. In table 7.1 I have summarised the roles taken by the physicist, or physicist and outreach officer. Where there is no outreach officer involvement in running an activity, either because a department does not have one or because the physicist has chosen to not involve them in their event, the physicists must take on each of these roles to some extent. Although I do not think it should be the role of the presenter to control the behaviour of the attending group, nor should they be expected to know how to deal with issues such as bathroom breaks or first aid for the young people, there will always be an element of group management involved.

Understanding these roles is important in managing outreach activity. On a basic level, realising that so many technical skills are involved can help in the design and planning of an outreach activity, and enable a realistic allocation of time for the development and delivery. For those departments trying to justify the creation of an outreach officer role, this might serve to highlight those tasks that will be required that the department does not currently have the capacity or skills to deliver. If these tasks are being taken on by physicists, then making explicit the variety and amount of work needed for successful outreach might enable better workload allocation or reward. This latter point is important to the sustainability of outreach programmes; where physicists have support from supervisors and managers to take part in outreach there is a need for this support to be reinforced through recognition, resource and reward, not just the approval to go

ahead and do the work. The roles outlined might mirror those required of an academic or school teacher (for example Harden and Crosby 2000), and literatures around professional development and recognition in both these areas will be relevant to any future research in this area. This study has included outreach officers who identify as physicists; further research might beneficially look more closely at the emerging profession of physics outreach officers.

Summary of different roles in outreach
***Technician**:* creating, ordering, storing and transporting various props and equipment for the events
***Event manager**:* marketing, booking, registration and point of contact for audiences, compliance and health and safety, booking and logistics for venue and staffing, hosting on behalf of the venue or lead organisation
***Content developer**:* idea generation, collaboration with (other) physicists, understanding of audience needs including education, development of specialist content items for presentation (e.g. animations, videos, graphics), understanding of physics
***Presenter**:* delivery, creation of main presentation, education and/or entertainment of audience, hosting on behalf of the content, role-model/advert for physics, group management
Evaluator: study design, questionnaire development, data collection and analysis, report writing

Table 7.1: Summary of different roles played out in the delivery of outreach activities. Such roles might be taken on by the participating physicist, an outreach officer, or another member of staff

7.2.6 Where do schools fit into this?

My original research interest assumed that for most physicists the term 'outreach' would be taken to mean outreach to schools. In this I was wrong; whilst a significant chunk of the physicist population I was able to reach are undertaking outreach to schools, or targeting schools audiences, the responses to the survey show that for most their understanding of outreach is much broader than that, and has more in common with the practices of public engagement, as discussed in section 7.2.1. In setting up the observations and interviews I left it to the outreach officers, physicists and teachers who were arranging my attendance at the events to determine what I saw and this again showed that whilst schools are a significant audience for physicists undertaking outreach, they are not the only priority in terms of influencing publics to be more engaged with physics. Perhaps more importantly, the discussions also showed the value to the participating physicist of an audience that has somehow chosen to be in attendance; this is not easy to achieve in outreach programmes not aimed at primary schools or A-level groups.

The four aborted observations, arranged through teachers and physicists directly rather than outreach officers, highlight the value of a dedicated role to liaise between the physicists and schools; so too do the case studies, where not only were the outreach officers seen making the events run smoothly, but this was strongly acknowledged by the physicists involved. Such a role acts as a node in the superposition of teacher and physicist, providing a reliable and informed contact point for both parties. This is not to imply that such roles are essential to making outreach happen; much activity happens without such coordination, but where outreach officers exist it appears that the physicists feel more supported in their efforts, and more able to target their activities to the audience, something that is particularly important when working with schools.

Respondents to the survey indicated that where outreach was considered to mean outreach to schools this was most often related to the prominence of recruitment or widening participation programmes in their institutions. Whilst acknowledged and important, these factors are not what motivates physicists to take part in outreach. For professionals seeking physicist participation in recruitment or widening participation programmes realising this is particularly important; if the physicists are not motivated

by the same drivers as those that underpin the outreach programme, then the content they produce and deliver will not necessarily produce the outcomes the programme seeks. This is a significant issue for government initiatives or funding such as that awarded to establish SEPnet; where funding comes with specific delivery requirements, such as to improve student GCSE attainment for example, there is no guarantee that the physicist involved will have the time, skills or inclination to tailor their materials to achieve this goal, or that they are the right person to be taking on this challenge. Failing to appreciate this has the potential to lead to unsatisfactory experiences for both the physicist and audience.

7.3 What does successful outreach activity look like to the physicist?

Overall, the activities I observed were considered successful by the participating physicists, yet by their own stated measures of success, predominantly audience engagement and questions, most were judged by me as showing limited evidence of success. Most of the physicists were content to have made it through their activity without any problems, rather than achieving the engagement and questions they desire. The most successful activities under these parameters were those where the audience had choice over their attendance, had well thought through visual aids or audience participation, and the delivery style was confident, clear, light-hearted without including jokes, evenly paced, and appeared polished. Appendix 11 presents an overview of the parameters for success that I observed in the outreach activities. In the following sections I shall explore the concept of good outreach and good evidencing of the success of outreach from the physicist perspective.

7.3.1 What is good outreach?

> And I think most importantly in the last few years there's a growing demand for scientists who are willing to go in and work with somebody else's agenda; and I think that is really, really important. Not just promoting my interests but actually supporting other people and exploring theirs. So I have done some projects with the Turner Contemporary Gallery in Margate for instance, with the local museum in Canterbury. Last week I was reading through, someone's

> drawn up a film script for instance, just to try and wear my scientist's hat but to do it within somebody else's environment. I think that is actually quite important.
>
> (Mike)

The quote from Mike above sums up the nature of good outreach for me; the action of a researcher going out into a given public, in a way that is informed by their own research interests, or as Mike puts it, wearing his 'scientist's hat' but simultaneously respectful of and responsive to the agendas that others have. What I was able to observe, and what the responses to the survey also highlight, is that most physics outreach is actually happening in spaces and formats that are very much the domain of the physicist. These can have additional benefits, in particular in meeting the goals of widening participation programmes where encouraging audiences to see themselves as part of university culture is key, or in terms of practicality, as rooms can be easily booked, with little or no cost, and travel is minimised for the presenter. By delivering in familiar formats the presenter is afforded control over their environment, and is likely to have had some practice, albeit for a different type of audience. So, good outreach remains an issue of perspective, underpinned by the values that Mike outlines, but in practice meeting much more pragmatic considerations such as Alice indicated so clearly: "I like being in control, I like answering questions and I like passing on knowledge". For the physicists, the major indicator that an activity has been successful is if the audience responds to them during and after the activity by paying attention, and particularly by asking questions. Such a response is often taken for granted as something that will result from the presentation or content alone, but I argue that good outreach is that which creates an environment within which questions can be asked, and the audience feels enabled to contribute to through questions or dialogue.

7.3.2 Creating good outreach

It is essential for any use of an academic's time that the question 'What are you trying to do, and how are you doing this?' be asked, and this is true of outreach. Given the different motivators demonstrated by the physicists across the survey and interviews, the purpose of any given session will be driven by the participating physicist's own

personal interests, but they will also be responding to departmental, institutional and national drivers, and in the case of schools outreach will be in response to the needs of an outreach officer or teacher. Under these circumstances it is not enough to cut down a talk already used for a different audience, and a little thought could go a long way to improving quality. The same is true for the production of slides or visual aids. In bringing out the focus of a presentation, it is also necessary to reduce the amount of information being used to get across any given point. Cutting down slides dramatically can help build space into the presentation for the audience to respond, and for schools groups in particular the remaining content can be tailored better to meet their needs as well as those of the presenter.

The use of humour and cultural references was a particular issue in the observations, and relates back to the tensions in definitions of outreach. The survey responses showed that the physicists are expecting to combine elements of entertainment, education, representation of their subject and sometimes also representation of wider issues around careers and diversity in science in their outreach delivery. Without specific training it is virtually impossible for the physicist to take on all of these roles, and in trying to achieve multiple outcomes, sometimes without the support needed to consider how they will achieve them, the final activity might fail to achieve any of the desired outcomes. If the physicist can be encouraged to focus on a particular outcome for the session, then they can follow delivery pathways specific to this approach. Such focus requires time and the capacity to learn from other work, and would require a considerable shift in physicist attitudes and behaviours with respect to outreach.

Whilst the issues around use of humour and cultural references highlight a wider issue with understanding and purpose of outreach, they also pose a significant practical problem. Some of the physicists I observed managed to be engaging and approachable through use of light-hearted language, but for the main part use of humour and popular culture references failed to engage their audiences. Humour and approachability can be developed through practice and general guidance, but audience response to jokes and popular culture references, such as those outlined in section 5.4, depends on the sharing of cultural norms or perspectives that cannot be guaranteed in a general public audience, and are unlikely when for schools outreach there is always a significant age difference between the presenter and the group, even when they are early career physicists.

Audience awareness is required to bridge these gaps in perspective, but developing deeper understanding of audience expectations and needs is not commonly covered by presentation or outreach training. One particular area of concern in this respect is the physicists' use of language around describing mathematics. By taking the position that the audience are not interested in, or not capable of being interested in, the mathematics being used to support or prove a given piece of physics, the presenter removes the audience's option to enjoy, or at least draw satisfaction from understanding, the mathematics being demonstrated.

These issues bring us back to two of the anecdotal issues I raised in the introduction; there are conflicting perceptions of outreach, particularly to schools. In my experience there are a significant number of senior academics who think they inherently understand the needs of young people or education, in part because they have been young or through school themselves, whilst conversely they believe that other physicists might not be able to understand these needs or work with these audiences because they consider 'other' physicists to be lacking in communication, or empathy, skills. Belief in inherent personal abilities can make it difficult for individuals to identify as needing to develop skills through training, or acknowledge the value that working on these skills might add to their activity. The creation of the mythical 'other physicist' who is lacking in social or communication skills presents a different challenge, by providing a scapegoat for issues with the perception of physics and physicists. In both cases increased peer observation of outreach activities might help to ameliorate these issues, particularly if guidelines for such observations could be introduced to ensure the physicist considers the perspective of the audience.

7.3.3 Creating good schools outreach

Schools audiences very rarely have any choice over their attendance at outreach activities, but such a choice makes a significant difference to the success of the event. The sessions I observed where the students had not chosen to attend were also those with the weakest talks; these were the presentations that included the most messages, with the most slides, with the busiest slides, and where the presenters had least experience as speakers outside of normal academic activities. It appears that there is a

temptation in this context for the presenter to try and take on too many agendas, presenting their research, the fundamentals of physics, careers information and the wider impacts of physics all in one presentation, in essence trying to ensure the visiting groups go away with the most information. Whilst it is unlikely that the physicist has been asked to ensure learning outcomes around a particular topic, for those sessions targeted directly at schools audiences, concerns about background knowledge appear in the language used by the presenters. This indicates some of the pressure felt by the presenter, and impacts on the success of the session.

My recommendation is for a new approach to be taken for these groups, giving them the same sort of talk that a public audience might receive, and through careful messaging and pre-event communications giving these students, even if they have not been given a choice to attend, the feeling of having been chosen, or at least that this session is being delivered specially for them. Development of such practice might require the input of a range of stakeholders, including teachers, school children, other group leaders such as those from the Scouts or Guides, and could benefit from the experience of other performance fields such as music or theatre, or programmes of outreach to difficult to reach audiences, such as those for young people out of education or training. Such work can also build on the concept of STEM capital developed through the ASPIRES[14] and Enterprising Science[15] projects, although this would need to be carefully introduced to the physicists to avoid them feeling overburdened by yet another agenda. Whilst most would be amenable to contributing to this agenda, the language and history of such a concept has the potential to make the outcomes of outreach seem an impossible task.

Given an increasing awareness in national bodies promoting STEM that issues in STEM uptake are caused at a young age, encouraging programmes of outreach to younger groups might create the illusion of choice due to the audience's enthusiasm for taking part. Such an approach could greatly improve the experience of all involved, but such an audience is not commonly prioritised by most outreach programmes. Alternatively, working with families and young people outside of the school system could encourage the physicists to move away from traditional teaching presentation styles and also allow

[14] http://www.kcl.ac.uk/sspp/departments/education/research/aspires/index.aspx
[15] http://www.kcl.ac.uk/sspp/departments/education/research/cppr/Research/currentpro/Enterprising-Science/index.aspx

the audience to choose their attendance, whilst still meeting institutional targets for the composition of the audience.

7.3.4 Evidencing success

> I was hoping to make these big experiments that cost a lot of money and that people might hear about in the news sometimes, something more concrete, something done by people that are actually doing that and not just something that appears in the news.
>
> (Vicente)

Given the mentions elsewhere of time constraints, practical solutions to evidencing the impacts of outreach will be valued by the physicists over the theory of good evaluation. To this end, and based on the outcomes indicated by the physicists to mark success as described at the beginning of section 7.3, simple measures such as the capturing of the number of questions asked, and the content of these questions, might allow some indication of how well the audience engaged with the topic presented. If possible, the opportunity for the audience to follow up with more questions at a later date, through social media or trackable websites, might provide indications of sustained engagement. Where the purpose of an outreach activity is something more complex with specific learning outcomes, something more detailed is needed. Such a project requires more thought, and both a wider awareness and a deeper understanding of the methods that might be successful in measuring such a change. Resource allocation for the physicist or outreach officer's own social science projects could be considered, but would require significant mentoring or skills development. Not all physicists and outreach officers would be interested in such approach, and one solution to this would be for the partnership of a social scientist from another department or organisation with the project.

In considering this I also question where the driver for the learning or attitudinal change is coming from; where an external agency, such as a funding body, is involved in setting the targets for an outreach programme the design and implementation of an evaluation programme may be better led by the funder if specific outcomes need to be measured. It is also essential that the desired outcomes are apparent from the outset, with the delivery

and evaluation designed with these outcomes in mind. In these instances the physicist begins to lose control over their contributions to the outreach programme, and delivery is then at risk of becoming formulaic. Such experiences are not good for either the physicist or the audience, and so highlight the need for outreach programmes to undergo longer term scrutiny. For the outreach sessions I observed there was obvious benefit where the physicist had the time, or motivation, to create an experience for the audience that was not based on a lecturing style developed for undergraduate teaching.

Where networks, such as SEPnet, are in place such scrutiny might come from regional posts or other partner institutions as critical friends; however, it is likely that the main driver for scrutiny of such programmes is the ability to report the numbers attending, numbers of physicists participating, and recruitment or widening participation data, as well as the factors by which individual institutions will measure success. Whilst we do not have specific guidance from the REF, the physics outreach REF Impact case studies imply that reach, or audience size, is a priority, along with changing behaviours in the audience. These particular cases use correlated, but not causal, indicators to mark behavioural change and I anticipate greater scrutiny for this element in the future; however, without the widespread employment of deeper evaluation techniques or long-term behavioural studies, producing clear evidence of this change will be difficult. I have not seen any such long-term studies emerge, which suggests such data are unlikely to be common in REF 2020. What can be improved, on the short to mid-term, is better on-the-day evaluation. Bearing this in mind I return to the idea of peer observations, this time as a tool not just for improving outreach quality, but evidencing the success of outreach programmes by looking at evidence of, and improvements in, audience response. This would need to be developed with the physicists, rather than introduced as a performance measure with the potential for abuse; used sensitively, such a scheme could encourage skills development and wider understanding of what the audience is experiencing through an outreach activity, as well as resource to support monitoring of activity outcomes. To raise the profile and approval for such a scheme, connection to a national competition or quality mark scheme, such as the HEA Teaching Excellence Programme, could add an element of external approval for practice and increase the value of such work to physicists' careers.

7.4 What can we take from the above to help prepare physicists for their outreach experiences?

> When we do public shows I would like people to go away, read BBC News Science and all those stories and take a keener interest in it. I personally feel if everyone valued what science does more then it is better for society. I think the problem is when science works, the public expect science to work, they expect scientists to go away do some magic and they have got a solution. They have cured something, they have got an answer and that is not how it works in real life. By doing these outreach events you show the work you put in to your research and how difficult it is to get an answer and therefore how valued it should be as knowledge.
>
> (Rob)

Given my pragmatic stance and practical inclination, it was always my intention for some of the outcomes of this study to be advice or tools to help improve the delivery of outreach. Whilst all the physicists I met were supportive of and enthusiastic about outreach, and I saw some excellent practice, I also saw how easy it is for the physicists to deliver uninspiring outreach and, importantly, not realise that this is what they are doing. Increasing external pushes to deliver against targets that do not motivate the physicists creates the risk that outreach increasingly becomes a burden rather than enjoyable, further decreasing its quality. What follows is a summary of my recommendations based on my findings; it is my intention to explore these recommendations with the various networks that support physics outreach in the UK and further afield.

7.4.1 Recommendations

1) The purpose of outreach needs clear definition, even if the methods of delivery do not. To this end I suggest that physics outreach is activity undertaken by physicists, delivered outside of formal education locations or not in the style of formal education, with the purpose of inspiring a target audience, passing on both knowledge and passion. This is not limited to recruitment activity, or activity aimed at schools, but is inclusive of elements of both.

2) Where outreach activities need, for funding purposes, to have educational attainment outcomes, this is best undertaken by educators rather than physicists. This is in line with the IOP decision to deliver Stimulating Physics as a teacher-led programme, but comes with the proviso that in the right environments or formats, academic physicists have a lot to add to such programmes.

3) Where outreach activities have, for institutional recruitment or widening participation purposes, a schools audience, consideration needs to be made of the constraints that such an audience are under. Acknowledging that the audience often does not have any choice over their attendance, special effort needs to be made to make attendees feel as though this activity is something that is for them. In particular, this means not making limited adaptations to presentations used for other purposes; even A-level students need to leave feeling inspired and empowered, rather than overwhelmed and confused.

4) All physicists, even those who are good at delivery or those who do not take part in outreach at all, could benefit from wider awareness of practice and the skills involved in good outreach. Instigation of a guided scheme of outreach peer observation and the curation of literature in this area, perhaps through existing networks, could contribute to this.

5) All physicists, even those who are good at delivery or those who do not take part at all, could benefit from better understanding of the possible measurable outcomes of outreach. In particular, given the emphasis all participants in the survey and case studies placed on audience interaction or engagement, it seems sensible that basic evaluation of outreach could be improved by capturing and reviewing audience interaction and engagement with the presenter.

Whilst outreach officers often act as an enabling factor in the delivery of outreach, I am concerned that they pose a potential barrier to the uptake of these recommendations by physicists; it might be considered that these recommendations are solely the task of the officer, rather than the combined responsibility of officer and physicist. In particular, taking on the role of peer observer may be difficult for some officers, depending on their status within their department. Mentoring or coaching training for the officers may help those who have suitable status to bring out the best in their physicists. For all officers, more must be done by academic champions to demonstrate the value of the

officers' specialist knowledge, perhaps leaning on the list of roles outlined in table 7.1 and professional boundaries shown in figure 3.2. Efforts must be made by departmental management to ensure the role is valued.

7.4.2 Looking beyond this study

> Well, I think you need to remember that it's subject and nation-specific. Physics has a particular need around outreach and different countries handle this stuff in different ways. I'm really proud of how much we do in the UK. It's caused by a special combination of factors, of willingness and of the way we're funded, but I would like to think there is more we could do.
>
> (Alexander)

This thesis has looked in depth at the situation for physics outreach across the UK, but has implications beyond these boundaries, both for physics internationally and for other subject areas. In the quote above, Alexander attributes much of what is achieved in the UK to a sense that the UK is somehow special. Based on the available literature and response to my survey on social media platforms I am less convinced of this. I received interest in my survey from physicists in the USA and across Europe. At both the 2012 *World Conference on Physics Education* and the 2014 European Physical Society (EPS) *Science in Society* conference I met a variety of outreach active physicists from different countries, each seeking to share practice and learn better ways of designing, targeting and evaluating their outreach activities. In each case I met outreach officers from different universities across Europe and South America with a common complaint of isolation, with international conferences their only route to develop their learning. All of this indicates to me that the UK is not unique in the issues it faces with respect to physics outreach, but that in some areas it is significantly advanced, such as the development of outreach networks. As discussed in chapter 2, the wide range of publications in which outreach is documented in makes it difficult to ensure that such studies are brought to the attention of those it might be useful to. Improved dissemination of outreach evaluations would help, and bodies such as the IOP, EPS and AAAS (American Association for the Advancement of Science) may all be well placed to support this.

A community of research is needed in this area if we are to be able to predict the behaviours of scientists with respect to participation in engagement and outreach. Bauer and Jensen (2011) made recommendations to the scientific community seeking 'robust, comparable data on PE activities', yet five years on we do not have shared understanding of the term public engagement, let alone comparable data. I have perhaps added to this problem with a new practice-based approach. Besley et al. (2013) highlight the issues with the current quantitative approaches in capturing data to predict behaviour, whilst Johnson et al. (2014) demonstrate the possibilities of a larger scale and systematic narrative approach. Based on my experience of observing the physicists in practice in their outreach, I believe that a longer-term study of outreach participation supplemented by interviews or another narrative approach may yield the robust data that Besley et al. seek, but that a co-creation approach might elicit better access to a wider range of outreach activities and attitudes to outreach. Such a study would be resource heavy but might, for networks like SEPnet, the Ogden Trust or the Institute of Physics, demonstrate the value, positive or negative, of the efforts they put in to supporting such endeavours.

Whilst my focus has been on physicists, many of the messages presented here are transferable to other research areas, particularly with respect to sharing practice and practical advice for outreach delivery. However, in the short term at least, I believe that the physicist community would benefit from a subject-specific focus to any resulting actions.

7.5 In conclusion

This thesis has presented a new approach to assessing physicists' perceptions of outreach, a new understanding of the meaning and purpose of outreach from the physicist perspective, and recommendations on how these perceptions and perspectives might be used to improve physics outreach programmes for the physicist, outreach officers or other similar management positions and, importantly, the audience. In choosing research methods for this study, specifically the case studies, I believe I may have identified a solution to some of the issues that exist around physics outreach, and

hope that this could enable skills development and better understanding of outreach throughout the physics community. Through this study, my own understanding, and appreciation, of the academics taking part in outreach has changed. Some of the black-and-white rules I had about outreach, for example the benefit of targeting school groups, need to be reconsidered in consideration of the physicists' own requirements for outreach.

Finally, my overall conclusion from this study is that there is a need for thinking space for all of those concerned. For the teachers who might desire to host or bring a group to an outreach activity, such time to prepare and review the activities will enable them to help their classes to get the most from their experiences, and not feel overburdened by them; this finding supports those of other reviews of informal learning (for example Wellcome Trust 2012b). For the outreach officers and managers, such time is essential if they are going to understand the physicists they are working with and the pressures they are under, and to take the time to also consider the needs of their audiences. Lastly, but by no means least, for the physicists, or indeed for any researcher getting involved with outreach and public engagement, these activities should not just be about the final delivery but about demonstrating the value the researcher places on the audience and their experience. For all three stakeholders this time needs to be formally allocated within workload allocation, as a sign of the value their institutions place on this work.

Whilst it is unlikely that I can alter the professional environment of the teachers, it may be that through dissemination of this work to physics subject bodies, outreach networks and individual physicists I may be able to encourage university departments to build this thinking space into the workloads and processes for outreach officers and physicists, through reduction in or reframing of targets, the establishment of clearer delivery boundaries or the reallocation of other workload. More likely, this study may act as a signpost to the officers and physicists to build more preparation time in themselves, but if they take this on by increasing the resource allocation in grant applications, or by setting careful targets, tangible benefits may still be felt. I hope that this study may act as a call to arms; through implementation of these basic principles, outreach and engagement activity can be improved for all those involved.

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Appendix 1: Survey Questionnaire

Physicists' perceptions of outreach – Welcome page

Title of project: Physicists' perceptions of outreach

Ethics approval: This study has been approved by the IOE research ethics procedures.

Principal researcher: Charlotte Thorley, Doctoral Student, Institute of Education, and Manager of the Centre for Public Engagement at Queen Mary University of London.

I would like to invite you to participate in this research project. Before you agree to take part you must be clear about what the project involves. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. If there is anything you do not understand, or if you would like any further information, please email me at c.thorley@qmul.ac.uk

What is the purpose of this study?

In my work I work with research staff and students to develop and deliver outreach activities. It is important that we understand the drivers that encourage staff and students to get involved, and any barriers they might face. Accordingly this project looks at the perceptions of outreach within a community of physicists. The focus is on outreach that has an audience of schools and young people.

Why have I been invited?

I am distributing this questionnaire to all physicists working in higher education and research institutions throughout the UK. In this way I hope to gather a solid body of information about physicists taking part, or not, in outreach activities. Please feel free to pass on details of this project to other relevant colleagues (physicists working in higher education institutions).

What do I do if I take part?

I would like you to complete an on-line questionnaire which should take no longer than 15 minutes to complete. The survey is completed anonymously and can be saved part way through. You can complete it wherever you have internet access and at any time.

What are the possible benefits of taking part?

All academics are increasingly under pressure to take part in outreach and public engagement activities. I hope that the questions in the survey will help us to understand these pressures better, and allow you to inform your own participation in such activities. If you would be interested in receiving a summary of this research when it is completed please leave me your email address at the end of the questionnaire.

Continue

Physicists' perceptions of outreach – Data Protection and Consent

Please read this carefully before continuing. You may wish to print this page out to keep.

Can I withdraw at any time?

Yes. You do not have to take part in this study if you don't want to. If you decide to take part you are still free to withdraw at any time and without giving a reason. This will not be known to anyone apart from yourself, and no-one will be aware of your participation or non-participation. As participation is anonymous and data are saved on every page it will not be possible for us to withdraw your data once you have completed each page.

Confidentiality

All data will be collected and stored securely in accordance with the Data Protection Act 1998. The data I collect will be treated as confidential, and be made anonymous before reporting. This means that when I write up the results no individual who participates will be identifiable.

Pressing 'continue' below represents your acknowledgement of the following statement of consent.

Statement of Consent

I have read the notes written above, and understand what the study involves. I understand that if I decide at any point in the questionnaire that I no longer wish to take part I can stop immediately. If I choose to give my name or contact details these will only be available to the researcher. Information I give will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.The information I have submitted will be published as a report, but confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications. I agree that my non-personal research data may be used by others for future research. I am assured that the confidentiality of my personal data will be upheld through the removal of any identifiers.

Continue

Page 1

Perceptions of Outreach: a survey of physicist views

There are increasing calls for scientists and engineers to engage with school students, both in the classroom and at research sites. I would like to know what you think about this. Is this a good use of your time? If so, how can you be supported? If not, why not?

The questionnaire will start with some general questions about public engagement for comparison to other studies. Towards the end of the questionnaire you will be asked some questions about yourself so that I can compare the results for different groups.

General Questions

1. How important do you feel it is that you personally, in your current post, directly engage with each of the following groups about your research?

Please rate importance on a scale of 1 to 5, where 1 is not important and 5 is very important.

Select one response per audience. 1 is not important and 5 is very important.

1 2 3 4 5

a. General journalists (i.e. in press, TV and radio)

b. Popular science journalists

c. Others in the media, such as writers, documentary and other programme makers

d. Students in schools and colleges

e. School teachers

f. Young people outside school

g. Policy-makers

h. Industry/business community (other than where directly concerned with funding your research)

i. The non-specialist public

j. Non-Governmental Organisations (NGOs)

2. Which of these groups do you think it is most important that they are engaged with current research?

- Policy-makers
- Industry/business community
- Popular science journalists
- General journalists (i.e. in press, TV and radio)

- Others in the media, such as writers, documentary and other programme makers
- Press officers in universities
- Students in schools and colleges
- School teachers
- Young people outside school
- The non-specialist public
- (NGOs) Non-Governmental Organisations
- Patients/patient groups
- None/don't know
- Other

If you selected Other, please specify:

Why do you say that?

3. Thinking about public engagement with, and communication about, science, roughly how many times in the past 12 months have you done each of the following?

None Once 2-3 times 4-5 times More than 5 times

a. Worked with teachers/schools (including writing educational materials)

b. Participated in an institutional open day

c. Given a public lecture, including being part of a panel

d. Taken part in a public dialogue event/debate

e. Been interviewed on radio

f. Been interviewed by a newspaper journalist

g. Written for the non-specialist public (including for the media, articles and books)

h. Engaged with policy-makers

i. Engaged with non-Governmental organisations (NGOs)

j. Worked with science centres/museums

k. Judged competitions

l. Other

If you responded Other, please give us more details about the activity.

4. What training, if any, have you had in communicating science to the non-specialist public? Do not include any teaching training you may have had.

(select all that apply)

- None
- Training to work with the media
- Training in writing for the non-specialist public
- Training in speaking to the non-specialist public
- Training in understanding the UK school education system
- Training in speaking to school children (of any age)
- Public Engagement training
- Impact training
- Informal training / experience

Other (please specify):

5. What are the implications of scientist being asked to engage **more** with the non-specialist public?

6. Scientists are in particular being asked to take part in **outreach** activities.

What does the term outreach mean to you?

7. Do you see a difference between the terms **outreach** and **public engagement**?

For the remainder of the questionnaire we will be talking about activities for school-aged young people only. This means children and young people between the ages of 5 and 19. This includes activities delivered in schools, on site at a research institute, on site at a Higher Education institution, or through a youth group or club.

Page 2

Engaging young people

8. How important do you think it is that school-aged young people engage with each of the following? Please rate importance on a scale of 1 to 5, where 1 is not important and 5 is very important.

Please select one answer per topic. 1 is not important and 5 is very important

	1	2	3	4	5
a. The scientific findings of research					
b. Areas for further research					
c. Policy and regulatory issues					
d. The wider social and ethical implications of research findings for society					
e. The potential benefits of work to members of the public					
f. The scientific process/the nature of science					

g. Scientific uncertainty

h. The enjoyment and excitement of doing science

i. The relevance of science to everyday life

j. awareness of career options in science

k. Fundamental science knowledge

l. Science curriculum content

9. How important do you think it is that you personally, in your current post, engage directly with school-aged young people on each of the following? Please rate importance on a scale of 1 to 5, where 1 is not important and 5 is very important.

Please select one answer per topic. 1 is not important and 5 is very important

1 2 3 4 5

a. The scientific findings of your research

b. Areas for further research

c. Policy and regulatory issues

d. The wider social and ethical implications of your research findings for society

e. The potential benefits of your work to members of the public

f. The scientific process/the nature of science

g. Scientific uncertainty

h. The enjoyment and excitement of doing science

i. The relevance of science to everyday life

j. To raise awareness of career options in science

k. Fundamental science knowledge

l. Science curriculum content

10. Looking at the list below, what do you think is the main reason for scientists and engineers generally to engage with school-aged young people?

- To be accountable for the use of public funds
- To contribute to public debates about science and scientific issues
- To contribute to discussions about the social and ethical issues science can raise
- To generate/stimulate additional funds for universities and colleges

- To recruit students to your subject
- To ensure the public is better informed about science and technology
- To raise awareness about your subject
- To raise awareness of science generally
- There are no other reasons to engage with this group
- To increase diversity in the scientific workforce, and access to scientific careers
- To create a more scientifically literate population
- If you selected Other, please specify:
- Looking at the same list again, what do you think is the second most important reason for scientists and engineers generally to engage with school-aged young people?
- To be accountable for the use of public funds
- To contribute to public debates about science and scientific issues
- To contribute to discussions about the social and ethical issues science can raise
- To generate/stimulate additional funds for universities and colleges
- To recruit students to your subject
- To ensure the public is better informed about science and technology
- To raise awareness about your subject
- To raise awareness of science generally
- There are no other reasons to engage with this group
- To increase diversity in the scientific workforce, and access to scientific careers
- To create a more scientifically literate population

If you selected Other, please specify:

11. Looking at the list below, what do you think is the main drawback to scientists and engineers engaging with school-aged young people?

- It makes them look bad in front of their peers
- It can send out the wrong messages
- It diverts money from research projects
- It diverts money from other, non-research, activities
- It takes up time that is better used on research
- It takes up time that is better used on other, non-research, activities
- There are no drawbacks to engaging with school-aged young people
- If you selected Other, please specify:
- Looking at the same list again, what do you think is the second main drawback of scientists and engineers generally engaging with school-aged young people?
- It makes them look bad in front of their peers
- It can send out the wrong messages
- It diverts money from research projects
- It diverts money from other, non-research, activities
- It takes up time that is better used on research
- It takes up time that is better used on other, non-research, activities
- There are no drawbacks to engaging with school-aged young people

If you selected Other, please specify:

12. In relation to the other things you have to do in your working life, how important is it to you that you find time to engage with school-aged young people?

- Not at all important
- Not very important
- Equally important
- Fairly important
- Very important

13. Would you like to spend more time, less time or about the same amount of time as you do now engaging with school-aged young people about science?

- I would like to spend more time
- I am content with the amount of time I spend on this now
- I would like to spend less time
- Don't know
- Why do you say that?

If you selected Other, please specify:

14. If you are involved in activities for school-aged young people, what age group do you consider to be the most important for you to engage with?

- 5-9 yrs
- 10-13 yrs
- 14-16 yrs (GCSE)
- 16-18 yrs (A-level)

Why do you say that?

15. Below are some things people have said about engaging with school-aged young people about science and engineering. Please indicate whether you agree or disagree for each statement.

Strongly Agree Agree Neither Disagree Strongly Disagree Don't know

a. Scientists who do outreach a lot are not well regarded by other scientists

b. Funders of scientific research should help scientists to communicate with school-aged young people

c. Scientists have a moral duty to engage with school-aged young people about the social and ethical implications of their research

d. I don't think my research is interesting to school-aged young people

e. The main reason to engage with school-aged young people is to get their support for science and engineering

f. I simply don't have time to engage with school-aged young people

g. I would not want to be forced to take a public stance on the issues raised by my research

h. Engagement with school-aged young people is best done by trained professionals

i. Engaging school-aged young people in science is personally rewarding

j. My research is too specialised to make much sense to school-aged young people

k. I would need help to develop a science engagement project

l. I would be happy to take part in a science engagement activity that was organised by someone else

m. Working with school-aged young people could help with my career

n. Engaging with school-aged young people is best done by senior researchers

o. Engaging with school-aged young people is best done by junior researchers

p. There are no personal benefits for me in engaging with school-aged young people

Page 3

Engaging young people continued

16. How easy or difficult do you think it is to get involved in activities engaging young people for those who want to do so?

- Very easy
- Fairly easy
- Fairly difficult
- Very difficult
- Don't know/can't say

17. How well equipped do you personally feel you are to engage with school-aged young people about your research?

- Very well equipped
- Fairly well equipped
- Not very well equipped
- Not at all equipped
- Don't know

18. What would encourage you personally to get (more) involved in activities that engage school-aged young people in science?

19. To what extent would you personally be encouraged to get more involved in activities to engage school-aged young people in science and engineering by each of the following?

A great deal *To some extent* *Not very much* *Not at all* *Don't know*

a. If my head of department/line manager were to give me more support and encouragement

b. If there were awards and prizes for me were to give me more support and as an individual

c. If it was part of getting professional status, such as chartered engineer or membership of my professional body

d. If it helped with my own career

e. If I was relieved of other work

f. If it would obviously contribute to a REF-able impact statement

g. If my department or institution was recognised by an award or prize

h. If it brought money into my department

i. If it was easier for me to get funds for engagement activities

j. If grants for engagement covered staff time as well as other costs

k. If it was easier to organise such activities

l. If I had some (more) training

20. What is stopping you from getting (more) involved in activities that engage school-aged young people in science? Please mark all that apply.

- I am already involved enough
- I am too junior
- I am too senior
- I am only in the UK for a limited period
- English is not my first language
- I feel that I am encroaching on Press Office work
- There is no senior level support
- Peer pressure
- There is not enough funding
- I need to spend more time on my research
- I need to spend more time teaching
- I need to spend more time on administration
- I need to spend more time getting funding for my research
- I would have to do it in my own time
- I need to engage a different public audience with my work, rather than school-aged young people
- I just don't want to
- Other (please specify):

21. Do other members of your department take part in activities that engage school-aged young people in science?

- Yes, most of them
- Yes, some of them
- Yes, one or two of them
- None of them
- Don't know

22. Are colleagues in your department generally supportive towards those who take part in activities that engage school-aged young people in science?

- Yes, very supportive
- Yes, fairly supportive
- Not particularly supportive
- Not at all supportive
- Don't know

23. Is your institution generally supportive towards researchers who take part in activities to engage school-aged young people in science?

- Yes, very supportive
- Yes, fairly supportive
- Not particularly supportive
- Not at all supportive
- It varies between departments
- Don't know

24. Do you think it matters if outreach activities have a cost implication for the participating school or group?

Page 4

In order for me to understand the views of different types of respondent, please tell me something about yourself. All replies will be treated in the strictest confidence.

Personal Details

25. Which best describes your main role at your institution?

- Research
- Research and teaching
- Teaching
- Management/administration
- Teaching and outreach/public engagement
- Research and outreach/public engagement

26. Which of these titles best describes your current position?

- Professor or above

- Reader or senior lecturer/researcher/fellow
- Lecturer, researcher or fellow
- Junior or assistant researcher or fellow
- Technician or other support staff
- Managerial or professional

27. From the list below, which most closely describes your current area of research interest?

- Astronomy, Astrophysics or Cosmology
- Atomic and Molecular Physics
- Atmospheric Physics
- Biological Physics
- Condensed Matter Physics
- Electro-optical physics
- Geophysics
- Mechanical Physics
- Medical Physics
- Nuclear Physics
- Particle Physics
- Theoretical Physics
- Thermodynamics
- Other

If you selected Other, please specify:

28. Which best describes your working status?

Employed full-time (>35 hours per week)

Employed part-time (<35 hours per week)

29. What is the principal source of funding for your research?

- Wholly or principally funded by a Research Council
- Wholly or principally funded by a Government Department
- Wholly or principally funded by a Higher Education Funding Council
- Wholly or principally funded by an EU research grant
- Wholly or principally funded by The Wellcome Trust
- Wholly or principally funded by the Royal Society
- Wholly or principally funded by another charity
- Wholly or principally funded by industry
- If you selected Other, please specify:
- If you are principally funded by a Research Council, which Council is funding your research?

AHRC BBSRC EPSRC ESRC MRC NERC STFC

30. To the nearest year, how long have you been working in scientific research / research and teaching, whether in academia or elsewhere? If less than six months enter 0, if more than six months but less than a year enter 1

31. What was your age last birthday?

32. Gender?

33. What is your ethnic origin?

White – UK, White – Mainland Europe, White – US, White – Other, Black – African, Black – Caribbean, Black – UK, Black – US, Black – Other, Chinese, Indian, Pakistani, Other Asian, Mixed race

If you selected Other, please specify:

34. Is English your first language

Yes No

If no, please identify your first language

Afrikaans
Albanian
Arabic
Armenian
Basque
Bengali
Bulgarian
Catalan
Cambodian
Chinese (Mandarin)
Croatian
Czech
Danish
Dutch
English
Estonian
Fiji
Finnish
French
Georgian
German
Greek
Gujarati
Hebrew
Hindi
Hungarian
Icelandic
Indonesian
Irish
Italian
Japanese
Javanese
Korean
Latin
Latvian
Lithuanian
Macedonian
Malay
Malayalam
Maltese
Maori
Marathi
Mongolian
Nepali
Norwegian
Persian
Polish
Portuguese
Punjabi
Quechua
Romanian
Russian
Samoan
Serbian
Slovak
Slovenian
Spanish
Swahili
Swedish
Tamil
Tatar
Telugu
Thai
Tibetan
Tonga
Turkish
Ukrainian
Urdu
Uzbek
Vietnamese
Welsh
Xhosa

35. Do you intend to work in the UK in the long term?

Yes No Don't know

Thank you for giving up your time to complete this survey. Your views will be treated in confidence. If you are willing to be contacted for potential follow ups to this research, such as an interview, please enter your contact details below. You can also indicate here if you would like to receive a summary of the research once completed.

36. If you are interested to know more about the results of this study, or would consider taking part in follow up activities, please provide me with the following contact details.

I am happy to be contacted regarding follow ups to this research: Yes/No

I would like to receive a summary of the research once completed: Yes/No

Your name:

Your telephone number:

Your email address:

Final Page

Thank you very much for your help. If you have any questions at all please contact me at c.thorley@qmul.ac.uk

Appendix 2: Observation field notes

	21st October, Cathedral University	
	Alice, Post Doc, arr. By Connor Trinneer on behalf of Linda Park	
	FE/HE College BTEC science groups optional lunchtime session	
	Light Gas Gun competition	
	Observations	**Reflection**
1	Alice is on her way to find us when we (Connor and I) go to get her. We bump into her on the stairs.	She's keen to get going, agitated that we haven't already left. Connor is very laid back.
2	She invites me to travel with them to the school	I'd already been invited by Connor. She wants to feel in charge of the situtation, potentially feels out of control or underinformed.
3	in the car we chat about the logisitcs of doing outreach, the timings and routines of schools, the issues with getting into schools and working with teachers.	
4	They also ask about the EdD, how it's different from a PhD, and why I am studying.	
5	Met by teacher at front desk, she's pleased to have Alice visit, and explains how this is both a normal and special event for the students. They are BTEC extended diploma students from applied science, forensics and medical sciences courses, all of which use physics. This is a regular science club session: students are given optional lunchtime sessions for credits; the students today have chosen to be there based on the information about the session.	this is an unusually well prepared intorduction to a school… this teacher has had many visitors in by the sounds of it, and is aware of what might put them off being there. Alice seems pleased with being greeted, but still agitated, and keen to get into the room.
6	we're taken up to the room. The science club have special dispensation to use the college boardroom, part of the principal's suite. There are refreshments at the back of the room.	school clearly takes this activity seriously, even still the teacher is keen to get the kids in so they are not clogging up the corridor outside the prinicpals office.
7	I settle at a desk near the front of the room with Connor. We're positioned as bystanders, neither the audience nor the deliverer.	
8	Alice moves straight to the computer desk/lectern to get the presentation set up.	Alice is using the technology to settle herself; once the set up is done there's nothing else that can interfere other than her own presentation or the kids. Safe zone near the computer and props, her space.
9	Students arrive. They fill up from the back and have brought their lunches.	the boardroom is not their usual environment; they are unsure of themselves and how to sit.
10	She is still at the lectern. This takes some time (approx 7 mins), she's very thorough, and tests videos before moving away from the desk. Connor and teacher both proffer help and are rejected.	shes dismissive of offered help, assserts her capability and control of the situation. She wants to be in charge.
11	Props laid out on the table.	
12	Teacher introduces the group to the session, including giving details of the science club facebook group. K moves out from behind the lecturn and introduces herself, explaining her role there today to talk and letting them know that they can ask any question they want at the end, including about uni applications.	professional, open, friendly
13	"I'm Alice Eve… well, Dr Alice Eve I only got that title recently so I'm very proud.	
14	Introduces the talk as presenting the details of a competition	
15	As she starts talking she's pacing backwards and forwards, speaking very fast, and even out of breath. This section is all about the competition.	I feel like shes not sure of the details of the competition (later confirmed)

16	Her pace slows after a few minutes, as the content is changing. This is her science now, the research she does directly.	She's happier delivering her research/science than the overall context
17	using props and diagrams, increase in technical information	some elements of her talk are black-boxed leaving some technical elements unexplained
18	"These light curtains measure by… …as you know"	Assumed knowledge, unlikely that a BTEC group would understand light use of light gates/curtains to measure speed.
19	"This is the science bit. We'll get through this and there are some awesome videos". She laughs.	She seems to be assuming that they won't find the technical elements interesting
20	Moves from descriing the light gas gun to how craters are produced on meteorites. Using lots of (beautiful) images of geological formations.	No connection between the two topics. I'm not sure why she's moved from one to the other.
21	"I forgot to say, I'm a geologist, working in a physics department". She's explaining more of her terminology now.	She seems happier explaining geology processes.
22	Students are still very well behaved, most seem attentive. A couple are subdued, looking into their food.	
23	"That was a very quick explaination of that, but that's essentially catatrophic disruption."	Shes speeding through content, but aware of it.
24	I finally understand what the talk is about! To model the impacts on meteors you use the light gas gun to fire projectile and an ice target to be the meteor. They are pitching a competition for the students to create the best possible clear water target, and come to Cathedral to try out the LG gun on their target.	
25	"The ice is cloudy, why is that? Can anyone hazard a guess? No?" She doesn't pause in the sentence. The students whisper a little, but none put their hands up, and she moves on before they have a chance to answer.	Maybe asserting that she thinks they wont know, maybe not sure they want to answer, probably the latter.
26	"does that make sense?" again, she doesn't allow time for them to respond.	Now I ownder if she feels time contrained and is worried about keeping on track.
27	She's explaining her own research now. "There are iron meteorites which are quite a lot like stainless steel but lets not get into that now."	Why has she introduced a concept that she won't follow up?
28	2 minute video of meteorites	
29	2 minutes of videos of LG gun firing at ice targets, including experiments that failed because the target wasn't made well enough. She discusses the usefulness of trying things out in science, that science is messy in real life	Real science being pitched. It seems really important to her that the students see all aspects of her work and the need for experimentation, as shes repeating her points and speaking particularly emphatically.
30	"Anyone know a property of ice? Come on, shout it out. What temperature does it melt at?" Student replies "0 degrees". She asks if anyone else has an answer, and then moves on. The backdrop is a triple point graph, which she only partially explains.	Again, no pause to allow the students to respond. This happens a few times in the next few minutes of talk.
31	In the bottom corners of her slides now are named moons and meteorites. She is pausing each time to tell us what they are called.	Again, a piece of information that is not directly related to the content of the talk. These seem to mean something to her, perhaps particularly beautiful or ones she has studied. This is not clear.
32	Details of applications for the clear ice target are hastily run through. She's stumbling over her words now, repeating herself and pausing.	She seems less comfortable again, could be time, could be content.
33	She relates taking part in the competition to UCAS applications	Assume this is to get them enthused to take part. I wonder how important UCAS applications are to this particular group?
34	Competition details have not been finalised. She starts telling them how to enter but stops because she doesn't know, and Connor chips in with some information.	

35	Q "what are the variables for the challenge?" K "If I were doing this the first thing I would look at is liquid nitrogen but that's just because I like liquid nitrogen." She's given them a clue	She is making up rules as she goes, and by giving them a hint has made their success more likely. I wonder if she will do this for all of the other classes she sees
36	The teacher leads the group into discussion to see if there is interest to take part. Two groups of students are clearly discussin their ideas, and the teachers go up to the front to ask questions. Alice is more animated now, but still fidgeting and pacing. . The students eventually follow suit, and ask questions about how to do well in the competition.	
37	Q" Are you a teacher now?" A "I do some teaching when my boss can't be bothered to do his..." she backtracks, and explains what a good course it is that she teaches on, and says she is pleased to do it.	
38	The students leave, A asks the teachers "was that the right kind of level?" Response "Oh yes, it was fine." They lead us out.	The teachers seem happy, but I'm not really sure it was the right level, so I am interested that they did not give her more feedback.
39	On the way to the car she asks Connor and I again about how it went "Was that alright? I guess we should talk about the details of the competition..." and the conversation goes on from there with Connor and Alice pinning down the details.	This discussion was animated and positive, she has clearly had a good experience and is keen to improve for next time. Connor is very laid back, and reassuring, seeming quietly confident about how the competition will run but open to her ideas. She has a voice here, and a chance to shape the activity.
40	We head to her office for interview.	

Appendix 3: Interview Schedule

Interview Schedule for physicist interviews

Introduce yourself and your project, remind them about choice and anonymity, and check consent form is signed.

- To get us started, can you tell me your name and a little about your job role, please?
- You recently took part in an outreach activity at INSERT NAME OF SCHOOL OR ACTIVITY where I was able to come along and observe the activity.
- Can you tell me a little about why you took part in or arranged that particular activity?
    - Is this a personal priority area?
    - Is this a priority area for your institution?
    - Do you think your particular research area has any influence on your choice to get involved?
    - Are there any other factors that influence your involvement? (job role, paid work, child in school, request from friend etc)
- Do you think it's important that physicists take part in outreach activities like this one?
    - is the content particularly important?
    - Is the target audience particularly important?
    - Is there a moral obligation to do this?
    - What are you hoping the participants will get out of the activity?
- Did you feel this particular activity was successful?

        - what makes you think that? If not, can you give me an example of one that was more successful?
        - What does successful outreach look like to you?
        - Is there a difference between successful for you and successful for the students? How about for the teacher?
        - Could the activity have been better? What would you need to help you achieve this?
        - Does departmental support/outreach officer make a difference?
- Additional points if not covered:
        - Do you see a difference between schools outreach and other outreach or public engagement
        - Do you feel valued for your outreach work?
- These discussions have been very useful, thank you. Is there anything else you think I should consider, or that you would like to add?

Don't forget to say thank you, and explain what happens next.

Appendix 4: Interview Transcript

Interviewer:	It's the 4th. Brilliant. Thank you.
	Just for the record, can you tell me your name and what your role is here at Industrial?
Marina:	My name is Marina Sirtis, and I am a Lecturer.
Interviewer:	You have been taking part in an outreach activity today, and thank you for letting me come in and observe it. What made you get involved with this particular activity?
Marina:	The school had specifically asked for medical imaging activity. It's something I enjoy doing, and I knew that I had material fairly ready to match what they asked.
Interviewer:	Do you feel like outreach activities are a priority for your institution?
Marina:	Unfortunately not (Laughter).
Interviewer:	How about for you?
Marina:	It's something I really enjoy. I would like to have more time for it.
Interviewer:	Yes. That's often the case, I find.
Marina:	Because, whatever they say, it's not what is priority, probably to most institutions. And, we have to juggle a number of other things, so...
Interviewer:	That makes sense. Do you think your particular research area lends itself to outreach, or does it make a difference on your-?
Marina:	Probably, yes. Because, medical physics is something people have heard about, and they see the real life application for it. There are a few things that can be hands on activities, and people see the immediate utility of it.
Interviewer:	Yes, that can make a big difference, I think. Do you think it's important that physicists do take part in outreach activities?
Marina:	I think so. Because physicists, well, at least we have this reputation for being detached from the real world. So, I think that even for a subject different from mine, so less applied subjects, I think it's important to show people what we are doing. What we are using their money for, as well. And, try to explain to them why it is important that knowledge progresses. And, what knock on effects there might be, or so on, in day to day life. So, for instance, most of the detectors that are used in medical physics, started off as detectors for particle physics first. So, even if people were not thinking of those specific applications, it had had a major impact on something that is closer to people than particle physics. And, I think, anyway, there are so many fascinating sides to physics, to non-applied physics, that it would be nice if people could be involved with it.
Interviewer:	So, you are hoping that they go away from these activities feeling enthused and informed about research?
Marina:	I would hope so.
Interviewer:	Yes. Do you feel it makes a difference what the audience is? Is there a particular target audience that's important?
Marina:	I think there are many important target audiences depending on what we are trying to achieve. Whether, it is school kids, to attract them into physics. Whether, it is general public with an interest in science, to get them more enthused. Whether it is just people as tax payers or policy makers, to try and persuade them that what we are doing is actually good, interesting and useful. So, there are many sides to it, and I guess that each activity, for each type of target audience, should be pitched at a different level.
Interviewer:	Do you prioritise any particular audience? For your own work?
Marina:	I must say that rather than me actively seeking my audience my activities happen when, typically, Sarah, or someone else, asks me to give a talk. Mostly, it's been schools, and I have given some talks to the general public, like Cafe Scientifique and similar institutions.
Interviewer:	You mentioned Sarah. Does it make a difference having an outreach officer in your department?
Marina:	I think so, because, she, or they, can keep connections with schools, with the public. So, they are much more aware than us of where some outreach activity is needed, and how we can tune them. They know a lot more than we do. So, they are very useful, also in advising us how to prepare an activity.
Interviewer:	It's good to have that sort of person around.
Marina:	Yes absolutely (Laughter).
Interviewer:	Did you think today's activity was particularly successful?
Marina:	They seemed to be quite engaged. So, that's probably a good gauge.
Interviewer:	So, is that what successful outreach looks like to you? The interaction from the young people?
Marina:	Yes, so, in general, the level off attention, of interest. They didn't ask any questions at the end though, which is something I would also use as a gauge of the level of interest, but they seemed to be quite interested. Probably you could observe them more than I could from the outside, but...
Interviewer:	They did seem engaged.
Marina:	Okay, thanks.
Interviewer:	So yes, you should be pleased. Do you think there is a difference between what success looks like to you, and what it looks like to the young people? Will the same activity be successful from both points of view?

Marina:	Probably, I would guess that it would be fairly easy to understand if it has been successful from their side, because we can probably perceive if they seem engaged. So, probably with young people, I think. If I see them engaged, I think it's been successful, and probably if they are engaged, they will go home thinking that I have learned something. Probably, might vary with different sides of the public, but...
Interviewer:	That makes sense. How about for the teacher?
Marina:	So, if it was successful for the teacher. That might be more difficult for gauge. Well, this one specifically seemed to be involved. She was nodding at times. But, I guess with a teacher, it will also depend very much on how it ties in with what they have seen in school, which the kids may not be aware of yet. Because, she mentioned something that related to some courses they would have to submit in the future. So, probably, with a teacher it also depends on whether we met the requirements of their syllabus, rather than just delivering an engaging activity.
Interviewer:	She was unusual for a teacher with the class like this. She was managing their experience in a way I haven't seen in many of the other observations.
Marina:	In which sense?
Interviewer:	Because she was- she did it in the talk before as well. She pre-empted the content that was coming up. She guided them into, you can relate this to X, Y and Z. She was very proactive. It's nice; it's just a different way of doing things.
Marina:	It was also a very small group.
Interviewer:	Yes.
Marina:	So it was probably easier.
Interviewer:	Is there anything that could have been better about today's activity, and what would you need to help you do that?
	There were a couple of moments when I thought "okay, I should improve that". Probably, the last part of the talk, after they had the experimental activity, was a bit of an anti-climax. If you have any ideas, clearly they are most welcome.
Marina:	Probably, I should have thought of something that would finish with that activity, and then just wrap it up, rather than adding new information. There was something that was crossing my mind, when we were doing the hands on activity, and I was thinking, "Okay, if I do it again, I should improve it". But, I think it was more about the design of the object, the layout of the little animals.
Interviewer:	But, you feel the changes you could make- you have the skills and the time, or the resource, to do what you need to?
	In this specific case, yes. So, clearly, the ideal thing would have been to take them into the x-ray labs and scan the same object, with x-rays, and that involves more time. Because, you cannot just acquire an image, you have to apply some corrections before you have a viable image. It could have been done with a group of 6, but, I think the last time the school came, there were 16 of them, and there wouldn't have been enough space. So, that's a resources implication that cannot be easily sorted with more money or similar...
Marina:	You end up having to change things on the go.
Interviewer:	That's all of my questions. Is there anything else you would like to just contribute, generally?
Marina:	Probably not.
Interviewer:	No? That's ok then. In that case, thank you very much.
Marina:	Thank you.
Interviewer:	See 10 minutes. It's not bad, is it?

Appendix 5: Codes for long-answer survey questions

Question 5:

A. Meaning of engagement

1. Informing, explaining, promoting public understanding, helping, Implications, relevance, utility of research, value of science
2. Explaining the process of science, what is done, why, limitations
3. Inspire people
4. Informing, stimulating, promoting understanding (other researchers, policy-makers, users)
5. Other

B. Type of activity

1. Listening, understanding public, involving people in science, science-based debates, science-based decisions, dialogue
2. Communicating with, or speaking to, the public, speaking in public, lectures, shows, social media
3. Media work, Writing general books, articles
4. Other

C. Motivations for engagement, or not

1. Good, worthwhile, important
2. Rewarding, enjoyable, develops skills
3. Accountability, duty of public funded researchers
4. Disseminating research, research findings
5. Raise profile of science, attract students, attract funding, careers, Counteracting poor media coverage, stereotypes
6. Reward, recognition (or not)
7. Availability of opportunities
8. Other

D. Who are the public?

1. Demographics, age, location
2. How are they perceived?
3. Other

E. Implications of pressure to do more

1. Need to reach new audiences, wider reach
2. Need to increase the amount of activity or size of audience

3. Infrastructure for support has been, or needs to be developed, time, resource, workload allocation
4. Other

F. Other

Question 6: What does outreach mean?

A. Mode of interaction

1. Communicating, promoting science
2. Educating, explaining
3. Discussing, dialogue
4. Engaging, getting involved
5. Recruiting, selling, promoting courses
6. Other

B. Target audience

1. General public
2. Schools, Children and Young people
3. Policy makers, industry, other adults
4. Other

C. Other

Question 7: Is there a difference between public engagement and outreach?

Appendix 6: Codes for observation data

A. Nature of outreach (roles and practical)
B. Understanding their audience
C. Entertainment vs education and freedom to attend
D. Valuing outreach
E. Personal connection to content and motivation
F. Other

Appendix 7: Codes for interview data

First attempt

A. Barriers to involvement
B. Definitions of outreach
C. Dissemination vs dialogue
D. Pushes to be involved
E. Recruitment, widening participation and diversity
F. Other

Final codes

A. Roles within outreach
B. Factors affecting their involvement
C. Nature of outreach
D. Understanding their audience
E. Entertainment vs Education and freedom to attend
F. Evidencing and evaluation
G. Other

Appendix 8: Physicist invitation to participate

Dear [INSERT NAME OF HEAD OF DEPT.],

I'm writing to you as Head of Department for Physics at your institution. As such I know you'll be more aware than most of the pressures put on all researchers these days to take part in public engagement initiatives. As well as leading the public engagement initiatives at Queen Mary University of London I am currently a doctoral student at the IOE, evaluating the impact outreach activities have on the scientist involved. Part of this is an online questionnaire of physicist perceptions of outreach.

Physicists' Perceptions of Outreach
https://surveys.qmul.ac.uk/physicsoutreach

I'd be really grateful if you could share this questionnaire with your colleagues. The final analysis will be shared with the IOP, RCUK and HEFCE to help them shape their programmes and policy. The questionnaire takes about 15 minutes to complete closes on **10th Nov**, and I'm looking for as many responses as possible.

Please don't hesitate to contact me with any questions, and many thanks in advance
Charlotte

c.thorley@qmul.ac.uk
0207 882 6114

Appendix 9: Physicist consent form

Participant consent form

Project Title: Physicists and Outreach: Implications of classroom interventions for scientists, students and teachers.

I would like to invite you to participate in this research project which looks at the relationship between physicists and their participation in outreach activities. I am exploring the ways in which participation in outreach activities is influenced by the perceptions of the physicists involved.

To help me achieve this I would be interested in forming a case study around your activity in delivering outreach activity. This would consist of an observation of you taking part in such activity, carried out by me at a time and place approved by you. This would be followed by a 20-30 minute interview, again at a time and place you have approved, or over the phone if more convenient to you. I will be transcribing the interview and subsequently analysing the conversation. I am able to make the transcript and my field notes from the observation available to you if you wish. Your participation is confidential; I will be storing the data securely on Institute of Education servers, and will report your responses anonymously unless you wish otherwise.

You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Please understand that you are free to withdraw at any time.

The final report will be a 45,000 word thesis and be submitted to the Institute of Education as part of my doctoral studies. I will also present some of my findings to conferences or in published research outputs.

Principal researcher:

Charlotte Thorley, Doctoral Student, Institute of Education and Manager of the Centre for Public Engagement at Queen Mary University of London.

c.thorley@qmul.ac.uk 0207 882 6114 or 07500 826151

Consent form

I confirm that I have read and understand the above and have had the opportunity to ask questions.	☐
I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reason.	☐
I agree to take part in the above study.	☐

Participant

Name: Signature: Date:

Appendix 10: School consent form

Teacher/Group leader information sheet

Project Title: Physicists and Outreach: Implications of classroom interventions for scientists, students and teachers.

Dear [INSERT the class teacher or group leader name],

You have recently arranged to take part in [INSERT activity name] with [INSERT HEI name], through contact with [INSERT Outreach Officer or scientist name]. As [INSERT Officer name] may have already explained [INSERT HEI name] is currently taking part in a research project I am carrying out, looking at the relationship between physicists and their participation in outreach activities. I am exploring the ways in which participation in outreach activities is influenced by the perceptions of the physicists involved.

To help me achieve this I am constructing a case study around the activity you are involved in, and will be coming to the activity to observe the interaction between the physicist leading the activity and you and your class/group. I am interested in the actions and responses of the physicist, so you are your class/group are not participating in my study directly. I am very experienced in the delivery of such activities, and as such may assist the lead so as to minimise the disruption I might otherwise cause in the room as an observer. If you have any concerns at all, please do not hesitate to contact me; I would be happy to answer any questions you might have.

I would like to take some photographs while I am observing. No pupil names would be recorded or presented with the images. Please indicate below if you are content for me to do so.

The final report will be a 45,000 word thesis and be submitted to the Institute of Education as part of my doctoral studies. I will also present some of my findings to conferences or in published research outputs.

Principal researcher:

Charlotte Thorley, Doctoral Student, Institute of Education and Manager of the Centre for Public Engagement at Queen Mary University of London.

c.thorley@qmul.ac.uk 0207 882 6114 or 07500 826151

I confirm that I have read and understand the above and have had the opportunity to ask questions. ☐

I give permission for the researcher to take photographs as part of the study outlined above. ☐

Participant

Name: Signature: Date:

Appendix 11: Summary of observations

Observation	Physicist	Institution	Activity	Props	Style	Choice to attend	School/ Public	Questions during presentation	Questions at the end	Slides
1	Alice	Cathedral University	Talk	Very good	Formal, questions, challenge	Optional science club	School	Yes	In person	Neat, well tested videos, mostly controlled information
2	Jonas	Coastal University	Lecture	No	Formal	Class activity	School	No	No	Very busy, lots of text, highly mathematical, too many slides
2	Bill	Coastal University	Lecture	No	Quite formal, humour, in a hurry	Class activity	School	Yes	No	Highly mathematical, controlled text, too many, but deliberately skipped
3	Wil	Historic University	Lecture	No	Quite formal, practiced humour	Optional evening event	Public + School	Yes	In person	Simple, strong images and maths, low text,
4	Rob	City University & Voluntary Aided School	Planetarium show and talk	N/A	Somewhat formal, questions	Class activity	School	Tentative	Yes	Video presentation and Stellarium (the sky tonight)

5	Vicente	Campus University	Straight lecture	No	Formal, fast	Class activity	School	No	No	Very busy, lots of text, untested videos, too many slides
6	Armin	Industrial University	Straight lecture	No	Formal, questions	Class activity	School	Tentative	No	Controlled text, strong images, untested animated presentation format
6	Marina	Industrial University	Talk and practical, teaching style	Very good	Formal, questions, practical	Class activity	School	Tentative	During practical	Controlled text, strong images, good practical
7	Alexander	Industrial University	Talk in context, practiced, warm up act	N/A	Somewhat formal, questions	Optional evening event	Public	Yes	Yes	Simple text, mostly images, strong images and maths
8	Mike	Cathedral University & Grammar School	Workshop: talk, play reading, activity	Good	Informal, questions, activity	Optional science club	School	Yes	During practical	Mostly images, not intrinsic to the presentation
9	Jonathan	Urban University	Straight lecture, limited props	Some	Formal, questions	Optional evening event	Public	Yes	One	Busy, good images not always clearly positioned, not particularly stylish