COMPARATIVE EVALUATION OF SCIENCE COMMUNICATION ACTIVITIES AND THEIR IMPACTS

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by

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Chapter 1

INTRODUCTION

1.0 THESIS OVERVIEW

The current research evaluates five science communication activities, comparing their impacts in terms of cognition (knowledge and understanding) and affect (feelings and attitudes). The activities were chosen to fit within a framework consisting of two axes, activity venue and activity target audience. The aim of the research was to compare activities delivered in different venues and with different target audiences, and to explore factors contributing to their impacts.

Depending on the nature of the activity, cognition and affect were measured directly, using responses to attitudinal tracking statements and questions testing scientific knowledge, and indirectly, by asking respondents to report their self-perceived changes in knowledge and attitude. For some studies both types of measure were used, allowing a statistical comparison of the indicators to be made.

The introduction to this thesis describes attitudes towards science in Britain and theories of learning, before discussing science communication theory and practice. The axes comprising the research framework, and the activities evaluated, are then described. Chapter 2 gives an overview of evaluation theory, and describes the research methodology and its justification. Chapters 3, 4, 5, 6 and 7 present the evaluation results for each of the activities. Chapter 8 provides a meta-analysis of the data, and compares the activities evaluated along the initial research axes. The axes were found to have certain limitations, so Chapter 9 proposes possible alternative axes that can be used to map a wider range of science communication activities than those evaluated in the thesis. In conclusion, the potential applications and limitations of such axes are discussed.

1.1 ATTITUDES TOWARDS SCIENCE

1.1.1 Public attitudes towards science among the adult British public

Public interest in science in the UK is generally high (House of Lords, 2000). A study conducted by the Wellcome Trust and Office of Science and Technology (Wellcome/OST, 2000) found that 74% of the British public agree that '*science is such a big part of our lives that we should all take an interest*', 84% agree that '*scientists and engineers make a valuable contribution to society*' and only 20% agree that '*I am not interested in science and don't see why I should be*'. A survey conducted previously in the UK and USA in 1988 had found that the proportion of respondents claiming to be interested in scientific discoveries was greater than the proportion claiming to be interested in sport (Durant *et al*, 1998). In addition, the British public considers science beneficial in making daily life easier and healthier, and in providing more opportunities for future generations (Wellcome/OST, 2000). Members of the public support Government funding of scientific research, even if it brings no immediate benefits.

Despite this interest in and general support for science, when it comes to regulation and control, members of the public are less optimistic. The Wellcome/OST (2000) survey found that 70% of respondents agreed that '*rules will not stop researchers doing what they want behind closed doors*', and 36% agreed that '*science is out of control and there is nothing we can do to stop it*'. However, there is a differential perception of the reliability of different sources of information, with university scientists being perceived as more trustworthy than Government scientists, or businesses or the media (Hargreaves *et al*, 2003).

It is widely recognised that *'the public'* is not a single homogeneous group, but consists of many *'publics'*, each with different attitudes, interests and values (Haste *et al*, 2005). For example, Miller (1999) classifies members of the public as belonging to one of three groups: the *'science attentive'* group are interested in science issues and rate themselves as well-informed; the *'science-interested'* public have a high level of interest but consider themselves less well-informed; the remaining *'residual public'* are neither interested nor well-informed. Further research has identified the existence of six attitudinal clusters with differing views about science (Wellcome/OST, 2000). The groups and their main characteristics are summarised in Figure 1.1.

Figure 1.1 *Attitudinal groups among British adults*

Percentage of the public	*Main attitudinal characteristics*	*Demographic profile*
20%	***Technophiles*** – positive about science and know how to access information but sceptical of politicians and the regulatory system	High income, higher social grades, well educated, young
17%	***Confident Believers*** – belief and interest in science because of the benefits it brings. Faith in the regulatory system and their capacity to influence government	Largely high income, well educated, middle aged, more likely to live in the south of Britain
17%	***Supporters*** – amazed by science, engineering and technology and able to cope with rapid change. Believe that the Government has control. Supporters are more likely than other groups to be interested in engineering and the physical sciences	Young, higher proportion of people still in education
17%	***Not Sure*** – uninterested in science or topical issues, perhaps because the benefits of science are often not apparent in their daily lives. Consequently, this group have few opinions about science	Typically low-income (including those on state benefits) with a low level of education
15%	***Not for Me*** – uninterested in science or topical issues whilst appreciating the benefits of science for the future and its importance to young people	Mostly low income women aged 65 and over and slightly younger male skilled manual workers
13%	***Concerned*** – interested in topical issues and know science is an important part of life, especially for their children. However, they are sceptical of those in authority	Higher proportion of women than men

Adapted from Wellcome/OST (2000)

1.1.2 Attitudes to science among young people

A recent study by Haste (2004) explored attitudes to science of 11-21 year-olds and found positive attitudes towards the perceived benefits of science similar to those among adults. Four different value sets, which were likely to be held by different demographic groups, emerged from the research. Descriptions of the value sets and their associated demographics are summarised in Figure 1.2.

Figure 1.2 *Value sets – British 11-21 year-olds*

Value set	***Demographic profile***
Green values – interested in the environment and ethical issues associated with animal experimentation. Concerned with the pace of science and interfering with nature	Girls
Techno-investor – reflected a generally buoyant attitude to scientific development. Supported technological investment. Trusted the government and scientists	Boys and young men
Science-oriented – reflected a general interest in science and technology topics and endorsed a '*scientific way of thinking*'	Young men
Alienated from science – reflected a lack of interest in science, and a lack of conviction that science can contribute to solving human problems. Liked clear right and wrong answers to problems	Younger girls, women in the workplace

Adapted from Haste (2004)

It is important to note that these value sets describe opinions rather than individuals. For research conducted with school students, there appears to be a difference between attitudes towards science in general, and attitudes towards 'school science'. While science generally is perceived as interesting and relevant, science in schools is perceived as boring (Ebenezer & Zoller, 1993; Sundberg *et al,* 1994). The latter study was of particular interest as it canvassed the views of students who had not elected to continue the study of science and, like the work of Haste (2004), found their attitudes towards science to be generally positive.

1.1.3 Attitudes towards science and physics among school students

The chapters of this thesis examining interventions aimed at school students involve activities focusing on physics. For this reason, attitudes towards physics and the physical sciences are given specific attention in the present discussion. Science education research has clearly indicated that attitudes towards school science decline from the point of entry into secondary education and over the course of secondary education (Young & Kellogg, 1993; House of Commons, 2002; Osborne *et al*, 2003). In the UK, this decline in interest is largely believed to start in earnest at age 11, although some research (Hadden & Johnstone, 1983; Pell & Jarvis, 2001) suggests it could be taking place before this. The House of Commons Select Committee for Science and Technology Third Report on Science Education from 14-19 (2002) describes school students' declining interest in science post-14:

> *'It is clear that the major problems lie at Key Stage 4... Many students lose any feelings of enthusiasm that they once had for science. All too often they study science because they have to but neither enjoy nor engage with the subject. And they develop a negative image of science which may last for life'*

The specific issues identified by the report within Key Stage 4 (ages 14-16) science are: perceived irrelevance, failure to engage in debate, repetitiveness, limited options, problems with practical and fieldwork, coursework, and the use of ICT. Research has also documented the negative shift in attitudes towards science as students progress through the educational system. For example, similar sentiments were raised in Osborne and Collins' (2000) study into pupils' and parents' views of the school science curriculum. The study also highlighted the pressures placed on teachers by a 'content-dominated and overloaded curriculum' where pupil performance was 'monitored ruthlessly' and emphasised that this caused much of the fun and excitement associated with scientific understanding to be sacrificed. Again, Key Stage 4 was identified as the stage at which much of this discontent started and a number of changes to the curriculum were recommended.

In cases where these attitudes have been examined in greater detail, it would appear that all sciences are not equal. While interest in the biological sciences have been found to remain reasonably constant throughout secondary school, there is a decline in students' interest in the physical sciences (Osborne & Collins, 2000; Williams *et al*, 2003; Spall, 2005). Research conducted by Spall (2005) indicates that the divergence in perception of the biology in comparison to physics begins at Key Stage 3 (ages 11-14) but becomes more dramatic at Key Stage 4. Several reasons for this divergence were indicated, including perceived difficulty of physics, its requirement for mathematical ability and students' views that physics lacked relevance and autonomy.

Research conducted by Spall (2005) showed that, as might be expected, students studying AS-Level Physics liked their subject, whereas students studying biology did not necessarily hold this view. More interestingly, these attitudes were found to hold true despite the fact that few students found physics easy, and many felt the subject carried a high workload and required good mathematical skills. The career prospects offered by physics are often cited as a reason for its choice at AS-Level and beyond (Woolnough, 1994; Reid and Skryabina, 2002; Spall, 2005). Physics has a reputation among students for being a 'difficult' subject. Several reasons have been put forward for the prevalence of this attitude, including the mathematical content of physics, its need for logical reasoning or abstractness and the counterintuitive nature of some of the concepts involved. Another possible reason for the widely held opinion about the difficulty of physics might be the abstruse nature of the mental constructs and principles that form the basis for many higher order concepts (Clement, 1982). In physics these basic constructs include key concepts such as mass, charge and energy, and fundamental principles such as mechanics and conservation laws

1.2 SCIENCE AND PHYSICS EDUCATION

1.2.1 How do individuals learn?

Much research has been done into the various ways in which people learn, and it is widely recognised that individuals learn in different ways (Marton *et al* 1984; Gibbs 1981 & 1987; Honey & Mumford 1982; Gardner 1983). This is important not only for the teaching of school subjects such as science, but also for lifelong learning. Theories related to learning can be roughly grouped by their emphases; different theories tend to focus on one of the following three aspects: cognition, affect or behaviour. The following sections give a brief overview of each aspect, in order that they can be referred to in later sections of the thesis.

Cognition

Theories emphasising cognition describe the way in which previously unknown information becomes firstly insecure and finally secure knowledge in the learner. Most of these theories take a constructivist approach, where knowledge is taken to be constructed by the individual through interactions with his or her environment. Examples of cognition-centred theories of learning include Piaget's (1955) 'lone scientist' model of how a child learns, building new knowledge through experience. Kolb (1984) describes a cycle of theory, practice, experience and reflection as crucial to the learning process, and Honey and Mumford (1982), who categorise learners as theorists, pragmatists, activists and reflectors, build on this. Gardner's theory of multiple intelligences (1983) identifies at least seven different intelligences that are possessed to different extents by different individuals, reflecting the ways in which they learn and interact with the world more generally. For educational purposes, multiple intelligences are often categorised more simply according to VARK (visual/auditory/read-write/kinaesthetic) characteristics, developed by Fleming and Bonwell (1998). By understanding the different ways in which students interact with their environment, teaching can be more closely tailored to their needs. In addition, modern cognitive science has modelled the complex way in which memory works, moving away from the idea that students' thinking is simply a box into which the appropriate knowledge can be stored (Redish, 1999). Memory is comprised of two components, the short-term (or working) memory, and long-term memory, which is structured and contains both declarative (facts and data) and procedural (rules and processes) information. Recalling information from long-term memory is dependant on context (Redish, 1999).

Affect

Theories that focus on affect or emotion include the Myers-Briggs Typology, which was conceived in the 1960s and is based on Jung's (1913) idea of introverted and extroverted personality types. The typology defines learners' personalities in four dimensions: extroversion/introversion, sensing/intuition, thinking/feeling and judging/perceptive. These characteristics are believed to be stable, that is, they do not change over time (Myers & McCaulley,1989).

Behaviour

Theories of learning behaviours include research into the teaching of habits through reward and reinforcement in animals (Pavlov, 1927), and Lave and Wenger's (1991) theory of situated learning, which argues that the learning environment plays an important part in the process. Another theory is Entwistle's (1988) idea that students may adopt either a surface or a deep approach to learning. Students taking the surface approach reduce the information to a series of unconnected facts to be memorised, ready to be reproduced in an examination or similar condition. Students opting for the deep approach attempt to make sense of the information presented to them, considering ideas and concepts, and forming links between different pieces of information and knowledge (Gibbs, 1981 & 1987). Unfortunately, surface approaches are very common among students in the UK, especially in universities, and more common in undergraduates who do not wish to continue on to postgraduate studies (Gibbs, 1981 & 1987).

1.2.2 Science education in England

All young people in England now study science until age 16, the end of compulsory education. Science can be taken by students as a combined course or, in some schools, as the separate options chemistry, biology and physics. However, instead of the desired effect of promoting science uptake post-16, compulsory science education appears to have encouraged many students to cease the study of science, and especially physics, at the earliest opportunity. For example, from 1985 to 2001 the total number of entries into A-Level Physics dropped from 46,606 to 30,701 (a decrease of 34%), despite a 10% increase in the total number of entries in all subjects over the same period (AQA, 2004). The AS and A2 system was introduced in 2002 for a number of reasons, among them to encourage students to continue further study in a broader range of subjects, which might include science subjects. However, because this new system has been introduced only relatively recently, its impact on science subjects' uptake has not yet been fully explored.

Declining physics uptake post-16 is not the full extent of the problem; the number of UK students electing to study physics at university has also declined, dropping from 9,990 to 9,045 (a decline of 9.5%) between 1996 and 2002 (Higher Education Statistics Agency, 2004). However, the total number of students gaining places on Higher Education courses had risen from 997,661 to 1,111,310 in the same period (an increase of 11%). Therefore, this represents a decrease of about 20% in the proportion of students choosing physics at university. This decrease in student numbers, when combined with changes in the funding structures of university departments, is threatening some UK physics departments with closure. Indeed, only 51 UK universities now offer first degrees in physics – a decline of over 30% since 1994 (Crace, 2004).

1.2.3 Factors affecting science subjects' uptake

Many of the negative attitudes towards school science can be attributed to the science curriculum, as mentioned previously in Section 1.1.3. Science education researchers have made a number of recommendations as to how these trends can be addressed in the school science curriculum. Osborne *et al* (2003) suggest that if school science is to capitalise on students' interests, it should be '*less retrospective and more prospective*', that is, focusing on the technologically-advanced future science can offer rather than looking backwards at well-established applications such as the Haber process. A review of the curriculum conducted by students themselves found that discursive and practical activities were popular, and ethical and controversial issues were of interest (Cerini *et al*, 2003). Work is currently underway in the science education field to reform the curriculum, and the Nuffield *21st Century Science* project has already piloted three new GCSEs. The emphasis is on scientific literacy skills, that is, providing school students with enough scientific knowledge and knowledge of the scientific method for them to become informed consumers of science, regardless of whether or not they will go on to become scientists. In fact, the choices within the syllabus enable the interests and ambitions of individual students to be reflected (University of York & Nuffield, 2004).

In addition to Lave and Wenger's (1991) concept of situated learning, a number of studies have highlighted classroom environment as an important factor affecting students' attitudes towards science (Haladyna *et al*, 1982; Talton & Simpson 1987; Myers & Fouts, 1992). Another factor may be the way in which physics is taught, and by whom. There is a concern that the number of graduates is falling, and that this shortage of graduates in turn leads to a shortage of such graduates becoming teachers (Williams *et al*, 2003). This may result in physics being taught by teachers whose main background and interest is in a science other than physics. Such teachers, despite their best efforts, may not teach physics with the same confidence and enthusiasm that a physics graduate would. This, in turn, exacerbates the problem if fewer students are inspired to continue the study of physics.

Clearly, then, there are problems associated with teaching physics in a curriculum-led, in-school context. The potential solutions to some of these problems may be constrained by factors beyond the control of individual teachers. A complementary approach is to provide extracurricular interventions (science communication activities aimed at school students) designed to stimulate or maintain students' interest in physics. Such activities encourage learning in a non-classroom setting. As well as having educational value, they aim to promote positive attitudes towards science and thereby increase the motivation to learn. Some of these types of activities will be further research in this thesis.

1.3 SCIENCE COMMUNICATION: A BRIEF HISTORY

Communication of science to non-specialists is not a new endeavour; both lecturing to the public and museums designed to promote public interest in science have a distinguished history. The Royal Society was founded in 1660 with the intention of becoming a forum for discussion of the many ways in which natural philosophy affects the everyday lives of people in England. In the 1700s the first institutes for adult education were founded, and women began to express a desire to be educated in science. Nowadays, one of the most well known venues for the communication of science to non-scientists is the Royal Institution in London. Count Rumford founded the institution in 1799, for both the advancement and dissemination of scientific knowledge. By 1801 the lectures held there were attracting such large audiences that Rumford could claim that they *"were not only the fashion, but the rage"* (Phillips, 1990). One of the most popular lecturers at the Royal Institution in the 1820s was Michael Faraday, who founded the famous Christmas Lectures for children, and who many consider to be the original demonstration lecturer.

Museums became important in the promotion of public interest in science in England with the establishment of the London Science Museum. The origins of the Science Museum lie in the nineteenth-century movement to improve scientific and technical education. Prince Albert was a leading figure in this movement, and he was primarily responsible for the Great Exhibition of 1851 to promote the achievements of science and technology. The profits of the hugely successful Exhibition were used to purchase land in South Kensington to establish institutions devoted to the promotion and improvement of industrial technology. At the same time, the Government set up a Science and Art Department that established the South Kensington Museum in 1857, from which the Science Museum and the Victoria and Albert Museum have developed. In the 1930s, the Science Museum in London opened a '*Children's Gallery*', incorporating dynamic models that could be operated by visitors using a series of buttons and levers. This, combined with the 'hands-on' approach adopted in the USA following the Sputnik launch in 1957, led to the opening of pioneer science centres such as the Exploratorium in San Francisco and the Ontario Science Centre near Toronto (Beetlestone *et al*, 1998). There are now numerous museums and science centres across the UK, and worldwide.

Print and broadcast media have also been important in the communication of science, from the introduction of the printing press in the 16th century to the ubiquity of television sets in homes by the end of the 1950s. Newspapers and television are a primary source of scientific information once people have left school (Worcester, 2001; Hargreaves *et al*, 2003), and have been identified as an important channel through which science communication can occur. There are, however, concerns over the way in which science is reported. These include misinterpretation or oversimplification of scientific facts, insufficient reporting of scientific method and context, and misleading communication of risk (Haste, 2004). Working more effectively with the media is a current priority within the science communication community (BA, 2004).

1.4 SCIENCE COMMUNICATION THEORIES AND PRACTICE

'Science communication', 'public understanding of science', 'public awareness of science and technology', 'public engagement with science and technology', and 'science in/and society' are all terms that have been used to describe the interface between scientists, educators, publics, policymakers and the media. Some of these terms are explained in more detail in the current discussion.

1.4.1 Public understanding of science and scientific literacy

A number of studies have documented the contemporary British public's low level of factual scientific knowledge. For example, the survey quoted by Durant *et al* (1989) found that only 34% of the British public knew that the Earth goes round the Sun once a year, and only 17% referred to experimentation and/or theory when questioned about the nature of the scientific method (although the tacit knowledge was somewhat higher). Research conducted by Hargreaves (2003) used a test comprising factual science questions. The average correct score amongst members of the adult public was only 34%, however for those with a science degree the average was somewhat higher (56%).

The Bodmer report (1985) was influential in highlighting public understanding of science as a critical issue for society. It argued that the pervasiveness of science in our society and its effects on personal activities and policy issues required all sections of the public to have at least some level of scientific understanding. It encouraged scientists to:

> *'learn to communicate with the public, be willing to do so, indeed consider it your duty to do so'*

Shortly afterwards, Thomas & Durant (1987) identified nine benefits of an improved public understanding of science. These include benefits to science through increased tolerance and funding of scientific work; benefits to economies from a supply of scientists and technologies; benefits to national power and influence where scientific superiority can play a part; benefits to individuals in terms of making sense of their everyday lives; benefits to society as a whole where citizens are informed voters, lobbyists and consumers; and intellectual, aesthetic and moral benefits. Around this time (1986), the Committee on the Public Understanding of Science (COPUS) was established by the Royal Society, the Royal Institution and the British Association for the Advancement of Science. Its remit was to improve the public understanding of science in the UK, and it included a funding scheme for public understanding of science projects and training workshops for scientists (Gregory & Miller, 1998). COPUS-funded activities have attempted to foster scientific literacy in the UK; 145 projects funded between 1999 and 2000 allowed some 1.5 million people to take part in science communication activities (Royal Society, 2004).

More recently, the Wolfendale report (1996) has summarised the objectives of the UK government's policy on the public understanding of science as

> *'to contribute to the economic wealth and quality of life of the Nation, particularly by drawing more of our best young people into careers in science, engineering and technology'*

and

> *'to strengthen the effectiveness of the democratic process through better informed public debate on issues of public concern arising in the fields of science, engineering and technology'*

Raising similar arguments to those of Bodmer (1985), Wolfendale highlights the importance of a scientifically literate British public in the areas of economic prosperity, democracy and culture (Pollock & Steven, 1997).

The term 'scientific literacy' is often used interchangeably with the term 'public understanding of science' (Laugkscii, 2000), and is seen to have similar benefits to individuals, economies and society in general. It was defined by Durant (1993) as '*what the general public ought to know about science*', and includes emphasis not just on scientific knowledge, but also on an appreciation of the scientific method. However, the 'public understanding of science' approach has been criticised for its assumption that greater scientific literacy is linked to increased positive attitudes towards science. Research has indicated that while there is indeed such a link, the interplay of knowledge and attitudes is complex (Sturgis & Allum, 2004). Evans and Durant (1995) explored this relationship more closely and found that while higher levels of scientific knowledge were linked with a greater interest in science generally, scientifically literate citizens were more likely to differentiate between different areas of scientific research. In fact, it was found that those with a greater level of scientific understanding were more likely to oppose controversial areas of research such as genetic engineering or nuclear power. So although public attitudes towards science in the UK are generally positive, controversies surrounding events such as the BSE epidemic call into question publics' confidence in the governance of science (House of Lords, 2000).

1.4.2 Public engagement with science and technology

Since the publication of the report of the House of Lords Select Committee on Science and Technology (2000) it has been acknowledged in the science communication community that the one-way transfer of information from scientists to non-scientists is not enough to counter the 'crisis of confidence' in science that certain sectors of society are experiencing. For this reason, there has been a move away from the '*deficit*' model of science communication typified by the public understanding of science approach where '*to know science is to love it*' (Sturgis & Allum, 2004). Instead, the House of Lords Select Committee report called for a new mood of dialogue:

> *'Today's public expects not merely to know what is going on but to be consulted; science is beginning to see the wisdom of this, and to move out of the laboratory and into the community to engage in dialogue aimed at mutual understanding'*

This approach moves away from the one-way, specialist to non-specialist communication associated with the deficit model, and towards greater engagement with sectors of the public. The dialogue model sees effective science communication as a multi-way communication between specialists and non-specialists. The publication 'See-*through science*' (Wilsdon & Willis, 2004), encouraged the dialogical communication process to move 'upstream'. That is, to encourage debate of scientific issues (such as nanotechnologies) where regulation frameworks are under development, as opposed to 'downstream' issues (for example genetically modified organisms) where the outcomes of any public dialogue are unlikely to impact on policy.

1.4.3 Science communication activities

A wide range of activities can be categorised as '*science communication*' activities. These activities have a variety of objectives, from fostering a general interest and understanding of science, to promoting scientific careers or influencing science policy (Research International, 2000). While some activities aim to encourage scientific literacy, others aim to promote positive attitudes towards science. Some activities aim to elicit the opinions of publics in order to inform scientific research or policy. Mapping of existing activities (Research International, 2000) allowed identification of the range and scope of such activities. The range of activities embraced by the term 'science communication', as identified in the Research International mapping project (2000), are shown in Figure 1.3.

Figure 1.3 *Types of science communication activities*

- Public lectures, consultations and conferences
- Advertising campaigns
- Open days and visits
- All science teaching
- Science centres and museums
- Media
- Festivals and roadshows
- Science clubs
- Information leaflets and helplines
- Local community meetings and networks
- Activities for public in public places
- Theatre
- Science websites
- School lectures, classes and discussions

Adapted from Research International (2000)

1.4.4 Potential benefits of science communication activities

The activities listed in Figure 1.3 above, if appropriately delivered, can contribute to greater scientific literacy, to promotion of interest in science and to positive attitudes and more effective dialogue between scientists and publics. The aims of such activities can include (but are not limited to) engaging the wider community, including school students, with scientific topics or issues, offering educational value and providing motivation for the study of science.

Such activities use a variety of mechanisms to interest and engage their target audiences. Palmer (2004) discusses the idea of '*situational interest*' in which school students are interested in a specific teaching or other intervention, as opposed to '*individual interest*', which describes a longer-term preference for, and interest in, a particular subject area. Research has shown that sustained situational interest may lead to the development of individual interest (Mitchell, 1997; Hidi and Harackiewicz, 2000), although this work centred on reading and mathematics rather than science.

1.4.5 Learning in informal settings

The learning experience in museums and science centres differs significantly from the way science is taught (and presumably learned) in schools. School science lessons set clear goals for student learning, and these are openly communicated to the students. In an informal setting, the students themselves decide their level of engagement and are responsible for their own learning. In science centres, the exhibits and programmes are usually extensively researched in order to be of maximum situational interest to students. The last decade has seen considerable growth in the area of research into learning in museums and science centres. Often a distinction is made between formal and informal learning, or 'school learning' and 'museum learning', although such distinctions can be vague, and a single definition of learning is often not adopted. Learning is by its nature multifaceted, and unbounded by time, institution or social context (Anderson *et al,* 2003; Mintzes and

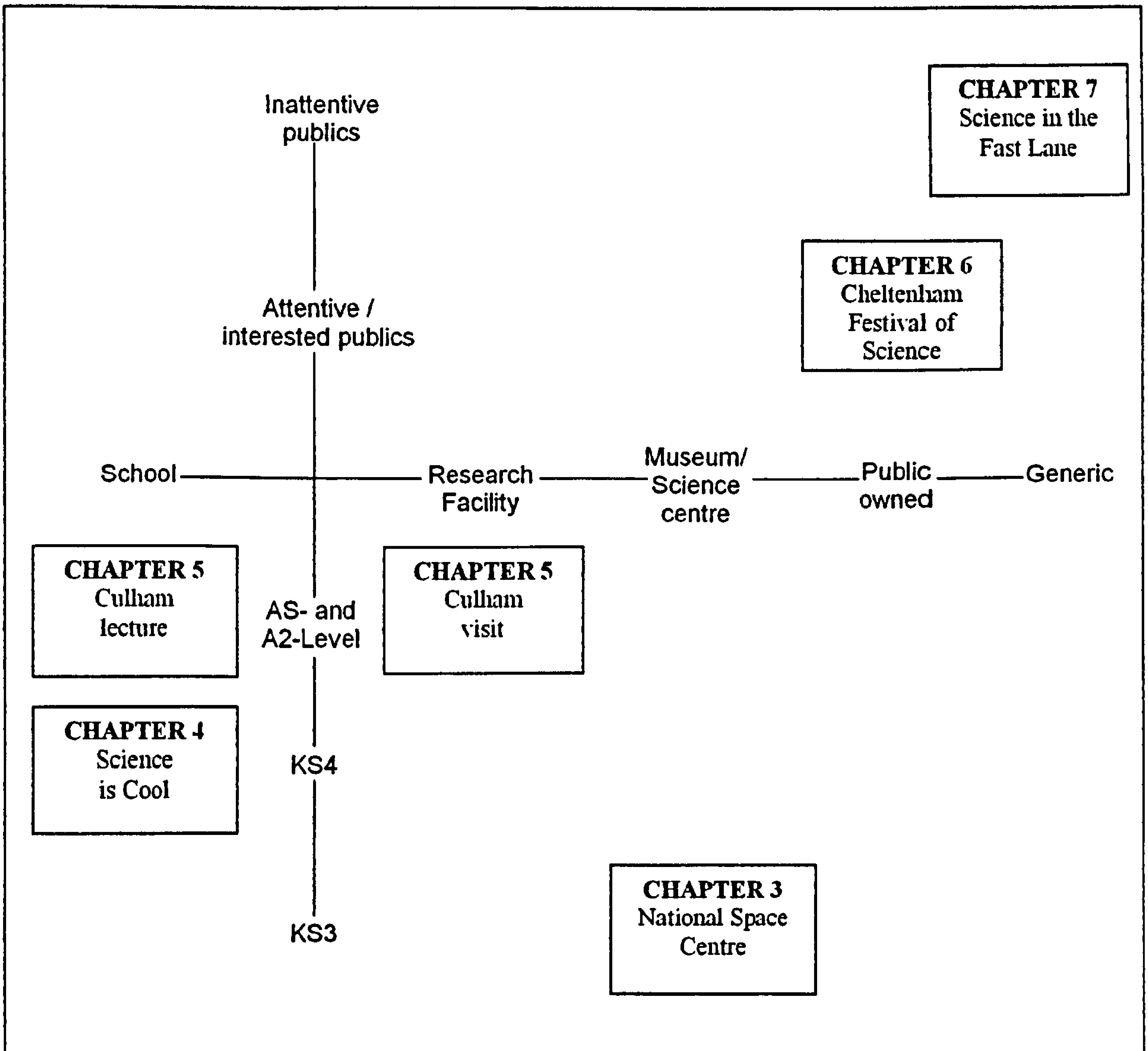
Wandersee, 1998). The human constructivist theory for learning acknowledges the uncertainties inherent in scientific knowledge, and describes it in terms of building of previous knowledge, linked in with everyday experience (Edmonson & Novak, 1993). Learning in an informal setting has been shown to encourage learning according to this constructivist theory (Anderson *et al*, 2003; Rennie *et al*, 2003). Another factor that encourages learning in an informal setting is its link with play, due to the emphasis placed on interactivity and enjoyment (Edeiken, 1992). Science centres and science museums aim to provide an enjoyable and educational experience for their visitors, and research has indicated that they have the potential to make a valuable contribution to science education, and can impact on affect and cognition (Wellington, 1990; Tuckey, 1992; Shamos, 1995; Ramey-Gassert *et al*, 1994).

1.5 FOCUS OF THE CURRENT RESEARCH

Good practice in developing and delivering science communication activities centres on successful targeting of audiences, appropriate selection of techniques and effective project management and evaluation (EPSRC, 2003). The current research focuses on evaluation as a means of measuring the impact of different activities. The terms 'evaluation' and 'impact' will be discussed in greater detail in Chapter 2, after the current introduction of the activities. The problem is that with so many diverse activities, how can the impact of, for example, a science festival be compared with the impact of a website, or a role model scheme? With so many activities and increasing competition for limited funding, a means of comparing activities would be a useful tool. As no such tool was in existence at the inception of the project, a framework, into which several activities would fit, was constructed. The activities were evaluated, focusing on their cognitive and affective impacts on audiences. By placing the activities within the framework, a comparison of the evaluative data could be made in Chapter 8.

Two axes were selected to provide the basis of the framework. These were 'activity target audience' and 'activity venue'. These axes, and the placement of the activities evaluated, are shown in Figure 1.4.

Figure 1.4 *Research axes*



Horizontal axis shows activity venue, vertical axis shows activity target audience

Figure 1.5 Activities included in the research

Chapter	Activity name	Provider	Brief description
3	National Space Centre visit	National Space Centre	A Year 8 visit to the National Space Centre including the planetarium show '*The Planets*' and the Challenger experience
4	Science is Cool	University of Liverpool	A liquid nitrogen demonstration lecture aimed at Year 10 audiences and held in school
5	Culham lecture	Culham Science Centre	A lecture about nuclear fusion aimed at AS- and A2-Level Physics students, held in school
	Culham visit	Culham Science Centre	A lecture about nuclear fusion aimed at AS- and A2-Level Physics students, held at Culham Science Centre and combined with a tour of the research facility
6	Cheltenham Festival of Science	Cheltenham Festivals	A 5-day science festival comprising talks, debates and interactive exhibits
7	Science in the Fast Lane	Graphic Science Unit	Activity at motorway service stations. Involved showing science tricks and distributing free activity packs

The activities described in Figure 1.5 were evaluated using similar instruments. As a result of applying similar instruments to the different activities, it was possible to gain an indication of the robustness of the instruments. This analysis is described in Chapter 8. The framework shown in Figure 1.4 was a useful research tool, allowing the implications of an activity's venue and target audience to be explored. However, as a result of evaluating the activities within the framework, some of its limitations were identified. These included interdependence between the axis categories, and limits to the numbers and types of science communication activities that could be mapped within the framework. For this reason, alternative axes, which can be combined to give a wider framework capable of greater generalisation, are discussed in Chapter 9.

The horizontal axis describes activity venue, and includes schools, research facilities, museums and science centres, 'public owned' venues such as theatres and town halls, and generic venues such as supermarkets or motorway service stations. The vertical axis describes the activity target audience, including school groups and various sections of the public. Miller's (1999) division between '*attentive/interested*' and '*residual*' (or 'inattentive') publics has been adopted. Having constructed the framework, it was decided to evaluate a range of activities that occupied different positions within it. This approach was designed to explore the different factors that might contribute to the impact of a particular activity.

Selection of activities

Activities were selected for inclusion in the research on an opportunistic basis. Contacts in the field were made by the researcher, and where it appeared that an activity would fit within the framework an evaluation approach was proposed. This arrangement was also beneficial to those delivering the activities, as it enabled their impacts to be evaluated externally and with minimal resources. For this reason, there was no shortage of potential activities to include in the thesis, and activity providers were happy to allow the researcher access to the audiences required to explore a range of positions within the framework.

The instruments used to evaluate the impacts of the activities are explained in Chapter 2. Figure 1.5 gives a brief description of each activity.

Chapter 2

EVALUATION METHODOLOGIES

2.1 INTRODUCTION

This chapter provides an overview of evaluation theory and methods, and describes and justifies the methods and instruments used to conduct the research in this thesis. In Chapter 1, the term 'activity' was used to describe the science communication activities evaluated. Of course, evaluation is not only conducted in the field of science communication. When describing evaluation in the current chapter, the more general terms 'intervention' or 'programme' are used, with the understanding that a science communication activity is a specific type of intervention. In the remainder of the thesis, the terms 'intervention' and 'activity' are used interchangeably.

2.2 EVALUATION THEORY

Evaluation has been described as a 'transdiscipline' (Scriven, 1996), and as an 'overarching metadiscipline' (Picciotto, 1999). Evaluation is important in any area of activity where issues of effectiveness and impact are to be considered (Rossi and Freeman, 1989). Chen (1990) describes six domains, and associated theories, in programme evaluation, derived from normative and causative theory. These domains and associated theories are summarised in Figure 2.1, and described in more detail in Sections 2.1.1 and 2.1.2.

Figure 2.1 Six domains relating to programme evaluation

Domain		Definition
Normative	Treatment	Treatment is the action or element that produces the change within a programme
	Implementation environment	Describes the environment within which a treatment is implemented
	Outcome	The intended and unintended outcomes of a programme
Causative	Impact	Assesses the impact of the treatment on the outcome
	Intervening mechanism	Investigates the mechanisms relating implemented treatment with outcome
	Generalisation	Provides information on how evaluation results can be generalised to apply to future systems

Summarised from Chen (1990)

2.2.1 Normative evaluations

Normative evaluations deal with the ways in which a programme's outcomes and delivery can be optimised by comparing the normative goals, treatments and environments to the actual programme activities. ***Normative outcome evaluations*** aim to improve the linkage between goals and outcomes, and aim to assist stakeholders in identifying and prioritising programme goals, as well as ensuring the realistic setting of such goals. ***Normative treatment evaluations*** consider the link between programme implementation and delivery and outcomes. The term treatment is defined as the actions into which the programme goals are translated, that is, the basic element that may or may not produce the desired changes. ***Normative implementation environment evaluations*** explore the environment in which the programme is delivered, considering, for example, participants, implementers, partner organisations and mode of delivery.

2.2.2 Causative evaluations

Causative evaluations aim to explore causal relationships between an intervention and its outcomes and impact. Types of causative evaluation include ***impact evaluation***, ***intervening mechanism evaluation*** and ***generalisation evaluation***.

Impact evaluations are the best-studied type of evaluation. They can be rigorous and evidence-based, and are closest to the image many science communicators would associate with the term, as it is similar to the summative (Dunn, 1981) or outcome (Posavac and Carey, 1989) evaluation that would typically be employed to judge the extent to which a programme had succeeded. An impact evaluation aims to judge the effect of the treatment on the programme outcomes. There are two lines of thinking within the field of impact evaluation, relating to if or how the goals of a programme should be incorporated into its impact evaluation. The goal-oriented approach (Tyler, 1942; Weiss, 1972) places the emphasis on achieving objectives as the key measure of a programme's success. However, this model has limitations – it can ignore potentially important unintentional outcomes, and the goals themselves may be vague (Scriven, 1972; Chen and Rossi, 1980; Weiss, 1972). Scriven (1967) introduced the concept of '*goal-free*' evaluation, where the evaluator explores all impacts of a programme with no prior knowledge of the stated goals. It is usual, however, to take the approach advocated by Verschuren and Zsolnai (1998), who concluded that:

> *'...the value of a program or a decision is determined not only by the achievement of its stated goals but also by its intrinsic ethical value and its performance for the stakeholders'*

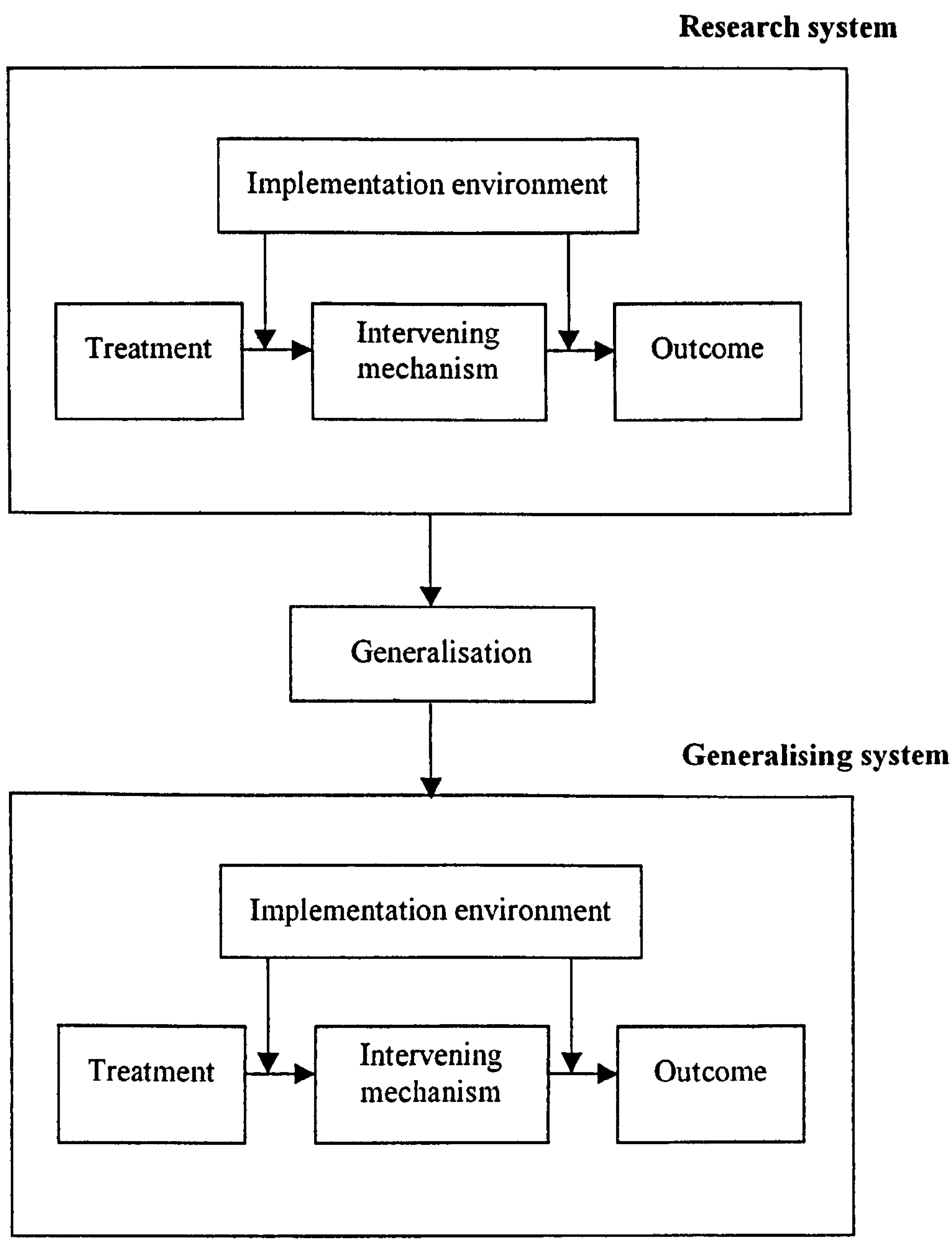
Impact evaluations often consider the stated goals of a programme while remaining open to the exploration of unintended outcomes.

Intervening mechanism evaluations aim to probe the relationship between the treatment and the outcome, with a view to identifying causal factors. In this way, the evaluation can provide information on the reasons for the success or failure of a programme – far more valuable than simply reporting whether or not it was successful. Another type of causative evaluations, ***generalisation evaluations***, explore the ways in which the results from an evaluation can be applied to other situations of interest to the stakeholders. If the facility for generalisation is not included in the initial evaluation strategy, problems associated with subsequent under- and over-generalisation can occur (Chen, 1990).

2.2.3 Relationships between domains

The ways in which these domains, theories and types of evaluation interact are summarised in Figure 2.2.

Figure 2.2 Relationships between domains



Adapted from Chen (1990)

2.2.4 Approaches used in the current research

The current research focuses on impact evaluation of several science communication activities. Intervening mechanisms are also considered where appropriate. By employing similar methodologies to a number of programmes, some generalisation is possible. The final chapter of this thesis proposes the basis for a framework which would allow greater generalisation of science communication activities and their evaluation.

2.3 EVALUATION RESEARCH METHODS

2.3.1 Experimental study design

Before-and-after and after-only designs were used, depending on the nature of the intervention. The before-and-after design was used with the school groups in Chapters 3, 4 and 5, where it was possible to gain responses from the students who would be involved in the intervention at both stages. This was not possible at the science festival (Chapter 6) or generic venue (Chapter 7) as there was no way of identifying audiences prior to the interventions. Control groups were not used, as one of the biggest problems with comparable study designs, especially in social science contexts, is that it is impossible to ensure that the control group and treatment group are comparable in every sense other than the intervention (Kumar, 1996).

2.3.2 Methods of data collection

The main methods available for collecting data for evaluative research, and their key advantages and disadvantages, are summarised in Figure 2.3.

Figure 2.3 Possible methods of data collection

Method	Advantages	Disadvantages
Observation	• Suitable for collecting data related to behaviour • Works well when subjects are involved in an interaction and unable to provide objective opinions	• Subjects may change their behaviour if they are aware they are being observed • Potential for observer bias or difference in interpretation between observers • Difficult to simultaneously observe and record
Interview	• Appropriate for complex situations • Allows collection of in-depth information • Responses can be probed further • Questions can be explained	• Potential for interviewer bias • Requires skill on the part of the interviewer • Time-consuming and expensive
Focus group	• Very 'rich' source of data • Allows group interactions to be observed as well as opinions gathered	• Time-consuming and expensive • Requires skill on the part of the interviewer as group dynamic is crucial to collecting useful data
Questionnaire	• Less expensive • Greater anonymity • Can be distributed in a number of ways	• Appropriate questionnaire design is crucial to success • Inappropriate for use with some groups, e.g. young children, illiterate adults • Potentially low response rate • Self-selecting bias • Clarification of questions not possible
Secondary sources	• Generally inexpensive • Convenience	• Validity and reliability problems • Data format may not match format required by researcher

2.3.3 Sampling

The manner in which a research sample is selected is important, as steps must be taken to eliminate or understand any bias present in the samples surveyed. A brief overview of the main sampling techniques available is given in Figure 2.4 below.

Figure 2.4 Possible sampling techniques

Type	Method	Description
N/A	Census	All members of the population to be studied are included
Random/ probability	Random	Sample members selected from the population randomly
	Stratified	Homogeneous strata within the population are identified. Random samples are then taken from each stratum
	Cluster	For larger populations, clusters are identified, potentially at a number of levels, until the stratified sampling technique can be used
Non-random/ probability	Quota	Sample members selected by means of a visible characteristic (e.g. gender) until quota is met
	Judgemental	Sample chosen based on researcher's judgement of who can provide the most valuable information
	Snowball	Sample selected using networks where each sample member is asked to recommend future sample members
Mixed	Systematic	Selection of the nth member of a population or stratum

2.3.4 Data collection methods and sampling techniques used in the current research

The current research used open- and closed-form questionnaires and structured interview schedules as the primary data collection instruments. These allowed information to be collected in a consistent manner between studies, enabling systematic analysis and comparison. In addition, data were collected for some studies from observation, electronic voting and secondary sources. In order to reduce bias, census rather than random sampling was used where possible in the schools research. In some situations, the census would be among a cluster (for example, a group of school students involved in an intervention) rather than a population.

2.4 DATA COLLECTION INSTRUMENTS

This section describes in more detail the data collection instruments used in the current research. A few questionnaire items differed slightly between interventions, although the main sections of the questionnaires were the same. Copies of all data collection instruments are given in appendices to the relevant chapters.

2.4.1 School groups questionnaires

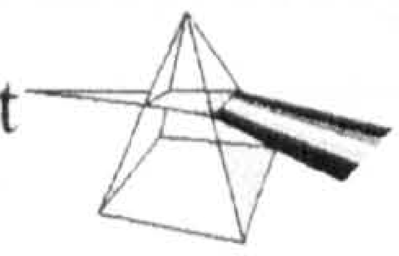
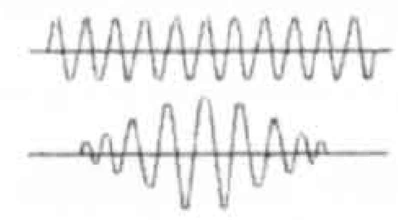
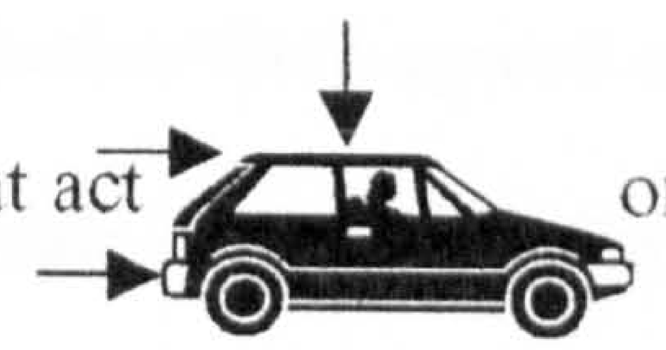
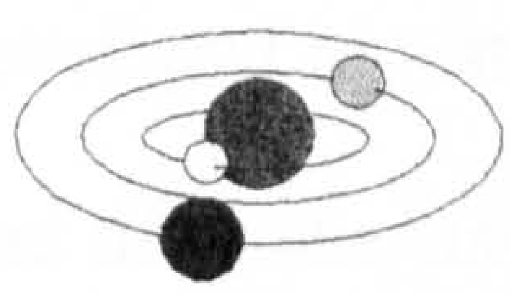
The before-and-after studies conducted in Chapters 3, 4 and 5 were designed to measure students' attitudes towards physics and their physics knowledge before the relevant intervention and then, by comparison with their views after the intervention, explore any changes in attitude and knowledge. Students were presented with an identical set of attitudinal statements and *'knowledge quiz'* questions at two stages, in the week before and the week after the relevant intervention. In addition, the second stage questionnaires included some items typical of *'after-only'* survey designs. These items aimed to collect, in a direct manner, students' opinions of the intervention, and asked students to rate their own self-perceived attitude and knowledge shifts. The structure of the questionnaires is described in more detail below.

Cover sheet

At both stages, the questionnaire cover sheet recorded each student's name, age, year group, gender and school. In addition, students were asked to record their names, so that each individual's responses before and after the intervention could be compared. This allowed a more detailed analysis than a population-based study alone. Students were asked to rate how they felt about physics on a five-point scale from '*really like physics*' through '*neither like nor dislike physics*' to '*really don't like physics*'. Students were also asked to rate their own ability in physics and to record how often they visited museums and/or science centres. The information regarding perceived ability and museum visits was recorded at the first stage only, as these variables were considered independent of the intervention. For Year 8 and Year 10 students, the cover sheet also included a definition of physics. This was recommended following research by Spall (2005), which found that many students were unable to clearly distinguish between chemistry, biology and physics. This is a likely consequence of the combined science course that most students take up to age 16. Often, lessons are simply labelled 'science' with no differentiation between the sciences. The description used bullet points and simple images to describe some of the main topics included in physics. A copy of the description is given in Figure 2.5.

Figure 2.5   *Description of physics included on questionnaire cover sheet*

Physics is about all of the below:

- Electricity  and circuits
- The way light  and sound work and travel 
- Gravity and other forces that act  on things and how things move
- Magnets  and electric motors
- Space, stars  and planets

Affective impact

The attitudinal tracking statements used before and after the interventions were those developed by Spall (2005) for use with students from Key Stage 3 to undergraduate level. The questions are shown in Figure 2.6.

Figure 2.6 Attitudinal tracking questions

Physics is an **interesting** subject
You need to be **good at maths** to do physics
Physics is more of a **boys'** subject
Physics is a **boring** subject
Physics is more to do with **remembering facts** than understanding ideas
Things I learn in physics **relate to my everyday life**
People who really like physics **don't mix very well** with other people
Physics is more of a **girls'** subject
Physics uses **difficult, complicated** words
Physics is an **easy** subject
Physics uses **easy, everyday words** but with a **different meaning**

Adapted from Spall (2005)

Students were asked to rate whether they agreed or disagreed with the same set of statements on a 5-point Likert scale before and after the intervention.

Cognitive impact

For each of the school-based interventions, ten multiple-choice knowledge quiz questions were developed to test students' knowledge of facts relating to the activity content before and after the intervention. These were presented in the form of a 'Quick Quiz' in order that, as far as possible, this part of the questionnaire was not seen as a formal test. This method is somewhat crude, and measures only the improvement of factual knowledge; improvements in procedural or conceptual knowledge were not considered in the present research because students had limited time available to complete the questionnaires. The difficulty level of the questions varied, and four control questions were included, which tested knowledge that was not included in the activities. The remaining six questions related to information covered during the intervention. An example question from the evaluation conducted in Chapter 3 is shown in Figure 2.7 below:

Figure 2.7 Example question

Which planet is closest to the Sun?

Jupiter	☐	Earth	☐
Mercury	☐	Venus	☐

Evaluation questions

The evaluation questions were designed to assess students' opinions on the intervention, as well as asking them to rate their own learning and attitudinal shifts. Students were also given the opportunity to comment in open questions in this section of the questionnaire, in order to explore some of the intervening mechanisms contributing to the impact of each intervention.

Survey of teachers

Teaching staff were asked to complete a short open questionnaire after the schools activities. The questionnaire had two aims: firstly to collect teachers' opinions of the intervention, and secondly to use teachers as a means of gauging the impact of the lecture on their students and exploring the intervening mechanisms between the intervention and its impact on students. Staff were also asked to record which subject and year group they taught, and their gender.

2.4.2 Questionnaire administration

Schools were recruited into each study by the researcher before the intervention, with the assistance of the activity organisers if appropriate. The first stage questionnaires were distributed by post, with a covering letter explaining the purpose of the research and the conditions under which the questionnaires should be completed.

For the benefit of future researchers, it is worth describing certain particulars of the questionnaire administration that allowed good response rates. For two of the interventions, (the '*Science is Cool*' lecture evaluated in Chapter 4 and the '*Great Balls of Fire*' lecture evaluated in Chapter 5) the researcher was able to offer the intervention to a school for no charge, in exchange for participation in the study. This was a favourable situation because administering the questionnaires before and after the activity involved considerable effort on the part of teachers, and providing an incentive such as the free lectures allowed a good response rate to be achieved for the studies. In addition, contact with teachers was prolonged while the date, time and arrangements for the lecture were confirmed (this was co-ordinated by the researcher). This allowed teachers to be reminded about the study, and gave them the opportunity to ask any further questions of the researcher. Where possible, the researcher visited the school on the day of the activity, to meet the teacher co-ordinating the questionnaire distribution, collect the first stage questionnaires and deliver the second stage forms. Again this worked well because it was possible to thank the staff involved in the data collection in person, and explain the purpose of the research. These factors contributed to the good response rates achieved for the studies involving the lectures that visited schools.

When the incentive of a free lecture and the close contact between researcher and schools was not possible, response rates suffered. This was particularly acute for the study in Chapter 3, where few schools included in the sample successfully completed questionnaires both before and after the visit to the National Space Centre, meaning that much of the data collected had to be discarded. Due to the location of the schools involved in the intervention, it was impossible for the researcher to visit the schools, and the study was conducted by post. Similar issues arose for the visits to Culham Science Centre, evaluated in Chapter 5, although the postal questionnaire issue was compounded by the fact that few visits take place, and often fewer than 10 students take part in each visit.

2.4.3 Structured interviews used for public audiences

Where audiences for an activity could not be identified prior to the intervention, an 'after-only' design was used. The primary data collection instruments used in both Chapters 6 and 7 (evaluations of Cheltenham Festival of Science and Science in the Fast Lane) are structured interviews, although data from other instruments such as questionnaires and electronic voting are included. The structured interview methodology was chosen because it can partly eliminate the self-selecting bias encountered with questionnaires because respondents are actively approached. In addition, structured interviews can allow inclusion of items that were consistent with items included in the questionnaires used for school groups. Also, in Chapter 6, data were collected by several interviewers, so it was important to maintain consistency among the responses. The structured interviews included the item '*before you came to* [intervention], *how did you feel about science*?' as an attempt to probe respondents' pre-existing attitudes. The interviews also included the items from the questionnaires asking respondents to rate their self-perceived attitude and knowledge shifts, as well as exploring opinions of the intervention.

2.5 DATA ANALYSIS

Data are analysed in two ways in this thesis. Firstly, each chapter evaluating a particular activity (Chapters 3, 4, 5, 6 and 7) includes an analysis of the data collected for the relevant intervention. This includes a descriptive analysis and an exploration of associations and differences within the data sets. Secondly, Chapter 8 presents a meta-analysis of the data collected in each of the individual studies, allowing some comparisons to be made.

2.5.1 Descriptive analyses

The types of analysis that can be performed on a data set depend on the way in which the variables are measured. The main types of measurement scale are summarised in Figure 2.8.

Figure 2.8 Types of measurement scale

Type	Description	Example
Nominal	Classifies data points into groups that have no inherent order	Gender, favourite newspaper
Ordinal	Classifies responses into subgroups that have an inherent order or ranking	Attitudes measured on Likert scale
Interval	Classifies responses on a scale that has its own units	Height, age

The data collected using the attitudinal tracking statements (described in Section 2.4.1) is ordinal in nature. The data collected for the knowledge quiz questions are measured on a nominal scale – responses were classified as 'correct' or 'incorrect'. The evaluation questions asked after the activities incorporate a mixture of ordinal and nominal data, and some of the demographic information collected was interval in nature. The statistical tests described below were used to analyse the data collected from the before-and-after studies in Chapters 3, 4 and 5. Statistical analysis was not performed on the data in Chapters 6 and 7, these data were analysed using descriptive methods.

Tests for association

Associations between pre-existing attitudes towards physics, self-perceived ability and frequency of museum visits were explored using a nonparametric ranking test. Ranking tests are typically used with ordinal data (Kinnear & Gray, 2004). They compare pairs of responses, and look at the polarity of the difference between them. There are two types of ranking test that can be applied to measure associations between variables measured on ordinal scales. Spearman's rho is equivalent to the Pearson correlation used to measure linear relationships between interval data. Although the formula is different, the coefficient obtained is equivalent. Kendall's tau statistics consider pairs of ranks, and the number of reversals of pairs required to transform one set into another. Because the variables all used 5-point ranking scales, Kendall's tau-b test was deemed the most appropriate to use.

Tests for differences

Statistically significant differences between responses to the attitudinal tracking statements before and after the interventions were explored. Nonparametric tests were used, because unlike their parametric counterparts these tests do not require that the data are normally distributed. The Wilcoxon test, a nonparametric equivalent to the related-samples t-test, was used to explore differences between attitudes measured on the ordinal Likert scales before and after the interventions. Whether ordinal data can be meaningfully analysed using parametric tests is a grey area (Kinnear and Gray, 2004). However where the data are in the form of a set of ranks

Chapter 3

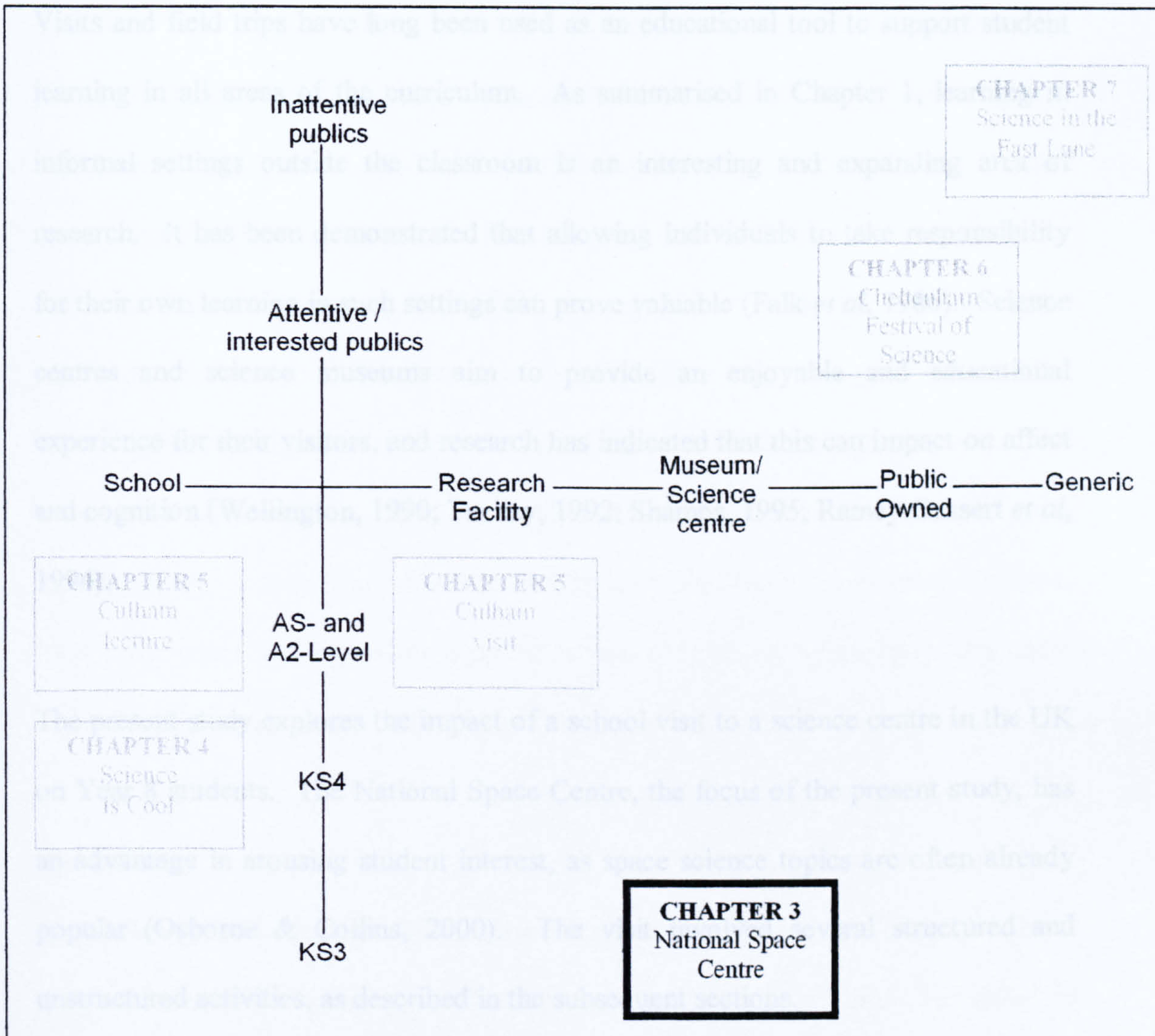
EVALUATION OF THE IMPACT OF A SPACE CENTRE VISIT ON THE COGNITIVE AND AFFECTIVE DOMAINS OF KEY STAGE 3 STUDENTS

PAGE

NUMBERING

AS ORIGINAL

Research axes



Horizontal axis shows activity venue, vertical axis shows activity target audience

Chapter 3 is an evaluation of the impact of a visit to the National Space Centre on the cognitive and affective domains of Year 8 students. The visit comprised a planetarium show, simulated space mission and time spent in the galleries. Students appeared to enjoy the intervention, and it was found to have a positive short-term impact on students' attitudes towards physics, as well as offering educational value.

3.1 INTRODUCTION

Visits and field trips have long been used as an educational tool to support student learning in all areas of the curriculum. As summarised in Chapter 1, learning in informal settings outside the classroom is an interesting and expanding area of research. It has been demonstrated that allowing individuals to take responsibility for their own learning in such settings can prove valuable (Falk *et al*, 1986). Science centres and science museums aim to provide an enjoyable and educational experience for their visitors, and research has indicated that this can impact on affect and cognition (Wellington, 1990; Tuckey, 1992; Shamos, 1995, Ramey-Gassert *et al*, 1994).

The present study explores the impact of a school visit to a science centre in the UK on Year 8 students. The National Space Centre, the focus of the present study, has an advantage in arousing student interest, as space science topics are often already popular (Osborne & Collins, 2000). The visit involved several structured and unstructured activities, as described in the subsequent sections.

3.1.1 The National Space Centre

The National Space Centre, situated in Leicester, UK, is a science centre incorporating an advanced multimedia planetarium, several galleries and the Challenger Learning Centre. Each school included in the present study visited a planetarium show and the galleries (including the '*Into Space*' tower) and took part in a simulated mission in the Challenger Learning Centre.

The planetarium show *'The Planets'*

The show *'The Planets'* takes place in one of the most sophisticated multimedia planetaria in the world, featuring advanced audiovisual facilities and an integrated electronic voting system. *'The Planets'* is a programme that explores the solar system and is aimed at students in Key Stages 2 and 3. It uses the planetarium's inbuilt audience response system which uses electronic voting to quiz students' knowledge about each of the planets as they are visited throughout the course of the show. This aims to reinforce the learning taking place during the programme. The programme communicates information regarding each of the planets in the solar system, including their size, structure, atmosphere and whether they have satellites. Each programme is delivered by a presenter who controls the voting questions and a series of video sequences, one for each of the planets.

The galleries

The galleries in the National Space Centre include a mixture of traditional museum-type exhibits (including rockets and satellites), and interactive exhibits. The galleries cover the way humans have explored space as well as space science, and include information on the latest space exploration programmes.

The Challenger Learning Centre

In the Challenger Learning Centre, a class simulates a space mission, and students take on the roles of astronauts and mission control scientists. Previous research into the impact of a visit to the Challenger centre on Key Stage 2 students (10 and 11 year-olds) had interesting results. For some students, there were significant gains in enthusiasm for science and in the appreciation of science in society, and a minority of students reported that they had been inspired to become scientists following the visit (this was more often the case for girls than for boys). However, there appeared to be no shift in attitude for half of the students involved in the study, and even some negative attitude shifts, especially amongst a minority of girls in whom the experience induced some anxiety (Jarvis & Pell 2002). The current study focuses on students in Key Stage 3 (12 and 13 year-olds)

3.2 METHODOLOGY

3.2.1 Data collection

Data were collected from Year 8 students from 3 schools visiting the Space Centre in 2003 and 2004. A questionnaire-based survey of students was conducted to measure indicators of attitudinal and cognitive change. The first stage questionnaires were administered in the week before the visit, and the second stage questionnaires were administered in the week following the intervention. The opinions of teachers were also sought using questionnaires administered after the visits. However the response rate was so poor that the teacher results are not included here.

3.2.2 Data collection materials

The study used closed-form before-and-after questionnaires to survey the impact of the intervention on the cognitive and affective aspects of students' thinking. Evaluation questions also surveyed students' opinions of the visit itself. Cognitive and affective impacts were measured both directly, using multiple-choice physics questions and attitudinal indicators, and indirectly by asking students to assess how much they felt they had learned, or if the way they felt about physics had changed.

The questionnaire consisted of four parts: A cover sheet, a set of attitudinal questions, a set of questions testing scientific knowledge, and a set of evaluation questions. Copies of the questionnaires are given in Appendix 3.1.

3.2.3 Pilot study

A copy of the script for '*The Planets*' (the planetarium show described in Section 3.1.1) was made available to the researcher for the design of the questions testing scientific knowledge. A pilot study was conducted in July 2003, primarily to ensure that these questions were pitched at an appropriate level. The level was found to be appropriate, and as no changes were necessary to the data collection materials the pilot respondents were included in the study cohort. Recruiting schools for the study proved challenging; the primary reason being that requests to participate needed to come from Space Centre staff as well as the researcher. In addition, the questionnaires were distributed by post and a number of the schools recruited into the study returned only the first or second stage questionnaires. The main study required responses from each student both before and after the intervention, so students from these schools could not be included in the subsequent analysis.

3.3 RESULTS

3.3.1 The study cohort

A total of 179 Year 8 students from three secondary schools took part in the present study. The responses of those students who had not completed the question regarding whether they had seen '*The Planets*' were removed, leaving 175 students. The study cohort is described in Figure 3.3 below.

Figure 3.3 *The study cohort*

Sample	*n*	*Age %*		*Gender %*	
		12	*13*	*Male*	*Female*
Student	175	38	62	49	51

All students were in Year 8

3.3.2 Association between attitudes, perceived ability and museum visits

Figure 3.4 shows associations between students' pre-existing attitudes towards physics and their perceived ability and frequency of visits to museums and science centres. The p values were obtained using Kendall's tau-b measure of association (as described in Chapter 2); the table presents both the correlation coefficients and the p values.

Figure 3.4 Association between attitudes, perceived ability and museum visits

	Rate physics ability as good		***Often visit museums and science centres***	
	τ	*p*	*τ*	*p*
Nature of the subject				
Like physics	0.38*	0.00	0.24*	0.00
Interesting	0.42*	0.00	0.34*	0.00
Boring	-0.33*	0.00	-0.22*	0.00
Relevant to everyday life	0.23*	0.00	0.24*	0.00
Academic demands of subject				
Easy	0.37*	0.01	0.18*	0.00
Remembering facts rather than understanding ideas	-0.18*	0.06	-0.13	0.01
Good at maths	0.11	0.19	0.09	0.09
Types of student				
More a boys subject	-0.03	0.65	-0.03	0.67
More a girls subject	-0.07	0.20	-0.08	0.30
People who don't mix well	0.04	0.41	-0.05	0.57
Communication of subject				
Uses lots of difficult words	-0.07	0.48	-0.05	0.27
Uses everyday words with different meanings	0.11	0.58	0.04	0.10

* *denotes association significant at the 95% confidence level or above*

These data indicate that students who rate their physics ability higher than average are more likely to have a positive attitude towards the nature of physics. The associations indicate that these students like the subject, find it interesting and relevant and reject the notion that it is boring. In terms of the academic demands of the subject, those students who rate their ability as high are more likely to agree that physics is easy, and disagree that physics is more about '*remembering facts than understanding ideas*'. Students who often visit museums and science centres outside school are also more inclined to like physics, find it interesting, easy and relevant, and reject the idea that it is boring.

3.3.3 Impact of the visit on students' affective domain

Figure 3.5 shows the responses to the attitudinal tracking questions before and after the intervention. The p values shown in the table were calculated using the Wilcoxon signed ranks test. The percentages shown in Figure 3.5 merge the responses for '*strongly agree*' and '*agree*' under the '*affirm*' heading, and the responses '*strongly disagree*' and '*disagree*' under the '*reject*' heading. The statistical analysis was conducted on the data before the responses were merged, that is, where responses were given on a 5-point scale.

Figure 3.5 Differences in responses before and after the visit

	Before %			*After %*			*p*
	Affirm	*Neutral*	*Reject*	*Affirm*	*Neutral*	*Reject*	
Nature of the subject							
Like physics	31	53	16	54	34	12	0.00*
Interesting	47	39	14	63	25	12	0.00*
Boring	21	39	40	13	38	49	0.00*
Relevant to everyday life	47	33	20	47	37	15	0.32
Academic demands of subject							
Easy	12	45	43	15	48	37	0.01*
Remembering facts rather than understanding	16	54	30	14	51	35	0.15
Good at maths	40	42	18	25	43	32	0.00*
Types of student							
More a boys subject	6	22	72	8	22	70	0.76
More a girls subject	3	26	71	2	24	75	0.17
People who don't mix well	5	22	74	4	22	74	0.93
Communication of subject							
Uses lots of difficult words	46	39	15	38	38	24	0.01*
Uses everyday words with different meanings	21	49	29	23	53	24	0.19

* *denotes difference significant at the 95% confidence level or above*

These results indicate that a visit to the National Space Centre had a positive impact on students' attitudes towards physics. Following the visit, respondents were significantly more likely to say they liked physics, agree it was interesting and reject the notion that it was boring. Respondents were also less likely to agree with (and more likely to reject) the idea that physics uses '*difficult, complicated words*' following the intervention. Students were also more likely to agree that physics is an easy subject after the intervention, and more likely to reject the notion that physics requires mathematical ability.

Over a third of students (36%) reported that the visit had changed the way they felt about physics. A further 40% felt the visit had not changed their opinion, and the remaining 24% were not sure. To explore this issue further, students were asked to describe the way in which their feelings about physics had changed. All of their responses indicated a positive shift in attitude:

> *"I thought physics would be boring but I was wrong"*
> (12 year-old female)
>
> *"Made me think - not just boring facts"* (13 year-old male)
>
> *"Shows it can be fun to learn"* (12 year-old female)

Chi-square tests were used to examine whether students who reported a positive shift in attitude were those who liked or were interested in physics before the intervention. No significant associations between the variables were identified.

3.4.4 Impact of the visit on students' cognitive domains

Figure 3.6 shows the percentages of students answering the knowledge quiz questions correctly and incorrectly before and after the visit. The p values were calculated using McNemar's test for differences, as described in Chapter 2.

Figure 3.6 Knowledge quiz responses before and after the visit

Question	*% Correct*		p
	Before	*After*	
Control – knowledge unrelated			
Which is the closest planet to the Sun?	93	95	0.45
Why are planets visible?	83	83	1.00
What type of fuel is burned at the centre of the Sun?	37	43	0.08
Roughly how long ago do scientists think the Big Bang happened?	21	19	0.85
'*The Planets*'-related questions			
What type of force holds the solar system together?	76	87	0.00*
What are Saturn's rings made of?	60	88	0.00*
Which is the seventh planet from the Sun?	71	77	0.16
What is the name of Pluto's moon?	32	39	0.09
What is Jupiter's red spot?	42	79	0.00*
Which is the hottest planet in the solar system?	49	70	0.00*

** denotes difference significant at the 95% confidence level or above*

Four of the six questions relating to information covered in '*The Planets*' showed a significant increase in correct responses following the visit. It is impossible to attribute this to the show alone; all of the schools involved also visited the museum galleries and took part in a Challenger mission. None of the control questions (those that were not related to the content of the presentation) showed a significant difference in correct responses before and after the intervention. This indicates that the high levels of significance measured for the other questions mean real learning has taken place, albeit only measured in the short term.

Students perceived the '*Planets*' show as educational: almost all students (99%) felt they had learned at least '*a little*' physics from the show, while 74% felt they had learned at least '*some*' physics and 26% felt they had learned '*a lot*' of physics. The use of the voting system appears to have helped reinforce students' learning. As one student put it:

> '[The show was] *good as you guess what you think and then find out if it is right'* (12 year-old female)

Other comments about *'The Planets'* included:

> *"Cool because they taught me lots of stuff and it was fun"* (13 year-old male)
>
> *"It really did make me learn something about the solar system. It was fun"* (13 year-old female)
>
> *"It is a good way of learning about space. The quiz is good"* (13 year-old female)

3.4.5 Evaluation questions

8 out of 10 students (84%) who saw *'The Planets'* felt it was interesting, and a similar proportion (79%) felt that the scientific level of the programme was *'about right'*. However a fifth (18%) felt it was *'too easy'*. Most students (77%) rated the length of the show as *'about right'* and most (80%) were satisfied with the pace of the show. Three-quarters (76%) agreed that *'The Planets'* was a *'fun way to learn about physics'*.

3.4.6 Students' impressions of the visit

Students were asked to write down their favourite and least favourite parts of the visit. The responses were grouped into categories and the results are shown in Figure 3.7.

Figure 3.7 Students' favourite and least favourite parts of the visit

Response	***Number of responses***	
	Favourite	*Least favourite*
Challenger mission	116	7
'The Planets' show	49	11
Galleries	3	23
'Into Space' tower	3	16
All	2	
Other	2	5
Waiting/queuing		10
Shop		10
Nothing		9
Leaving		8
Lunch/Food		7

Students appeared to enjoy the Challenger mission and *'The Planets'*, as these were the most popular activities. The least popular were the galleries and the '*Into Space'* tower. Reasons for their unpopularity included:

> *"Going round the galleries not much hands on or stuff to do"* (12 year-old male)
>
> *"Galleries cos we had no guidance just left to get on with it"* (13 year-old female)
>
> *"The space tower cos I climbed up all the steps and there was nothing there"* (12 year-old male)

Some students in the sample disliked *'The Planets'*, saying it was '*too easy'*. The show is targeted at Key Stage 2 and 3 audiences, and Year 8 students are at the upper end of this range. This is reflected in some of the comments. Despite this, students' overall impressions of the visit were generally positive.

> "[I] *don't find physics boring anymore"* (12 year-old female)
>
> *"Exciting and fun and interesting"* (13 year-old male)

"I think that the Planets show was good because it put facts into a fun interactive form people will enjoy and remember" (13 year-old male)

"Excellent and a cool way to learn" (13 year-old female)

"It was a fun way to learn physics rather than writing notes in a classroom" (13 year-old female)

3.5 DISCUSSION

3.5.1 Results summary

Overall, students responded well to the visit. Following the visit, students were significantly more likely to accept the idea that physics is interesting, reject the idea that it is boring, and agree that they liked physics. This generally positive shift is likely to be due to the fact that the students found the visit enjoyable, and that a range of activities were included in the visit, appealing to students with different interests and learning styles. Students were also significantly more likely to reject the notion that physics uses difficult language following the visit. This highlights the effective design of the National Space Centre's exhibits and programmes, where the science is presented in an accessible manner and the programmes are appropriately targeted. A third of students reported that the visit had improved the way they feel about physics.

A significant positive shift in physics knowledge was indicated for four out of six questions relating to the subject matter in '*The Planets*', with no shift in knowledge for 'control' questions (those that did not relate to the programme content). Students enjoyed the show, and felt it was educational, although some students found the content too easy – probably because the target audience for the show also includes younger students. This finding highlights an issue facing any programme developer:

how to design a programme appealing to students with a range of abilities without alienating the least able or patronising the most able. Interestingly, some students commented that the ease with which they answered the questions during '*The Planets*' was a positive aspect of the programme, whereas some felt it was detrimental.

3.5.2 Impact on Key Stage 3 students

The results described in this section of the work show a positive, short-term impact on the affective and cognitive domains of students visiting the National Space Centre. As discussed in Chapter 1, it is believed that the decline in attitudes towards science begins at Key Stage 3, so positive interventions at this time may be crucial to countering this trend. Indeed, the results of the present study indicated that the positive shift towards 'liking physics' was not limited to those students who held an existing interest in the subject.

It is, of course, unclear how this positive impact will change over time, and whether the situational interest stimulated by the visit to the National Space Centre will develop into a longer-term individual interest in students. There was an indication, however, in some of the students' comments that they themselves anticipated long term effects, for example, '[I] *don't find physics boring anymore*'. This emphasises that evaluation of any medium and long-term impact of interventions such as the one considered in the present study are increasingly important in research in this area. However, such work is not straightforward. In addition to methodological issues such as timescale and difficulty in tracking students, it is incredibly difficult (if not impossible) to measure a causal relationship between an intervention such as a science centre visit and a long-term shift in attitude. This presents one of the most interesting challenges currently facing science communication researchers.

Appendix 3.1

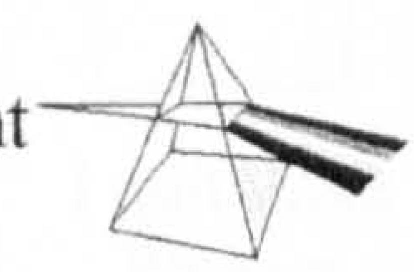
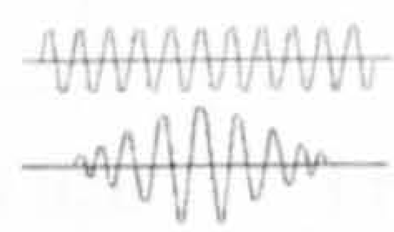
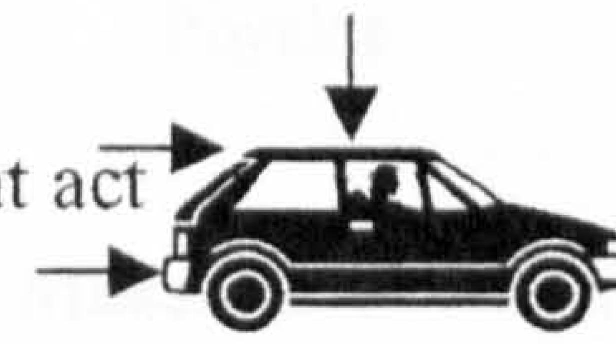
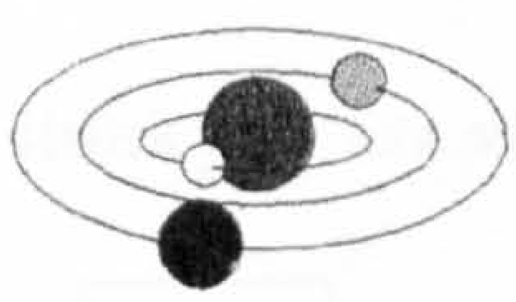
Data collection materials

- Student questionnaires, pre- and post-intervention (NB attitudinal questions and quiz questions were identical at both stages – these pages of the questionnaire are only included once)

Physics Questionnaire

We are doing a big study to see what people think of some of their school subjects, like Science. We are especially interested in what you think about Physics.

Physics is about all of the below:

- Electricity  and circuits
- The way light  and sound work and travel 
- Gravity and other forces that act  on things and how things move
- Magnets  and electric motors
- Space, stars  and planets

Now for the questions...

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name............................ Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

☐	☐	☐	☐	☐
I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics

Outside school, do you ever visit Museums or Science Centres?

☐	☐	☐	☐	☐
Lots of Times	Often	Sometimes	Very Occasionally	Never

How good do you think you are at Physics?

☐	☐	☐	☐	☐
Really Good	Quite Good	About Average	Quite Bad	Really Bad

NSC/SPACETHEATRE/PRE

These questions are about Physics

Physics is an **interesting** subject

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

You need to be **good at maths** to do physics

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

Physics is more of a **boys** subject

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

Physics is a **boring** subject

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

Physics is more to do with **remembering facts** than understanding ideas

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

The things I learn in physics **relate to my everyday life**

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

People who really like physics **don't mix very well** with other people

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more of a **girls** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **difficult, complicated** words

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is an **easy** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **easy, everyday words** but with a **different meaning**

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Quick Quiz

The following questions are about some Physics topics. Answer the questions by ticking the box that you think is the right answer.

Here is an example of how to answer the questions:

Which of the following television soaps is about life in London?

Eastenders	☑	Coronation Street	☐
Hollyoaks	☐	Neighbours	☐

And now for the Quiz...

Which planet is the closest to the Sun?

Jupiter	☐	Earth	☐
Mercury	☐	Venus	☐

Planets are visible because...

They emit light from their surfaces	☐	They reflect the Sun's light	☐
Gases in the planets' atmospheres emit light	☐	They reflect light from the stars	☐

What type of force holds the solar system together?

Gravity	☐	Magnetism	☐
Electric fields	☐	Inertia	☐

What are Saturn's Rings made of?

Rock and ice	☐	Gases	☐
Dark matter	☐	Frozen oils	☐

Which is the seventh planet from the sun?

Saturn	☐	Jupiter	☐
Uranus	☐	Neptune	☐

What is the name of Pluto's moon?

Titan	☐	Miranda	☐
Io	☐	Charon	☐

What is Jupiter's "Red Spot" ?

Iron Oxide on the planet's surface	☐	A large crater	☐
A hurricane	☐	A volcano spewing red gas	☐

Which is the hottest planet in the Solar System?

Mercury	☐	Earth	☐
Saturn	☐	Venus	☐

What type of fuel is burned at the centre of the Sun?

Methane	☐	Hydrogen	☐
Oxygen	☐	Ammonia	☐

Roughly how long ago do Scientists think the Big Bang happened?

550 million years ago	☐	15 billion years ago	☐
150 billion years ago	☐	550 billion years ago	☐

Thanks!

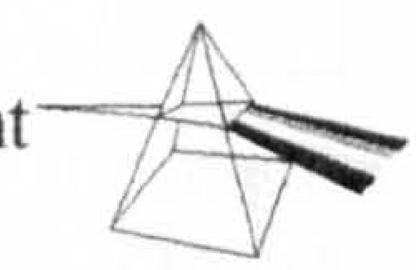
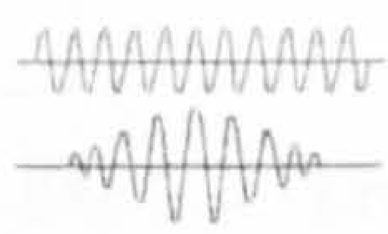
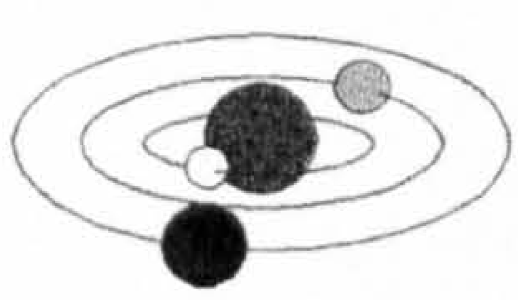
Physics Questionnaire

We are doing a big study to see what people think of some of their school subjects, like Science. We are especially interested in what you think about Physics.

We would also like to know your opinion on your recent visit to the National Space Centre, and especially what you thought about the show ***"Planets"***.

Please take a few moments to answer the following questions

Physics is about all of the below:

- Electricity  and circuits
- The way light  and sound work and travel 
- Gravity and other forces that act  on things and how things move
- Magnets  and electric motors
- Space, stars  and planets

Now for the questions...

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

☐	☐	☐	☐	☐
I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics

NSC/SPACETHEATRE/POST

These Questions are about the Space Centre Visit

Which parts of the Space Centre did you visit?

☐ Planets Show	☐ Galleries/ Exhibition areas	☐ Into Space Tower	☐ Challenger mission	☐ other, please state ....

If you visited the Galleries, did you use the Space Trails?

☐ Yes	☐ No	☐ Don't Know

What did you think of the "Planets"show?

☐ Very Interesting	☐ Interesting	☐ Neither Interesting nor Boring	☐ Boring	☐ Very Boring

What did you think of the length of the show?

☐ Much Too Long	☐ Too Long	☐ About Right	☐ Too Short	☐ Much Too Short

What did you think of the pace (speed) of the show?

☐ Much Too Fast	☐ Too Fast	☐ About Right	☐ Too Slow	☐ Much Too Slow

What did you think about the Science in the show?

☐ Much Too Easy	☐ Too Easy	☐ About Right	☐ Too Difficult	☐ Much Too Difficult

Do you think the "Planets" show is a fun way to learn some Science?

☐ I strongly agree	☐ I agree	☐ I neither agree nor disagree	☐ I disagree	☐ I strongly disagree

How much Science do you think you learned from the show?

☐ A Lot ☐ Some ☐ A Little ☐ None

Overall, how would you describe your Space Centre experience?

☐ Very Good ☐ Good ☐ Neither Good Nor Bad ☐ Bad ☐ Very Bad

For you, what was the best bit of the Space Centre visit and why?

For you, what was the worst bit of the Space Centre visit and why?

Do you think that visiting the Space Centre has changed the way you feel about Physics?

☐ Yes ☐ No ☐ Don't Know

If YES, in what way?

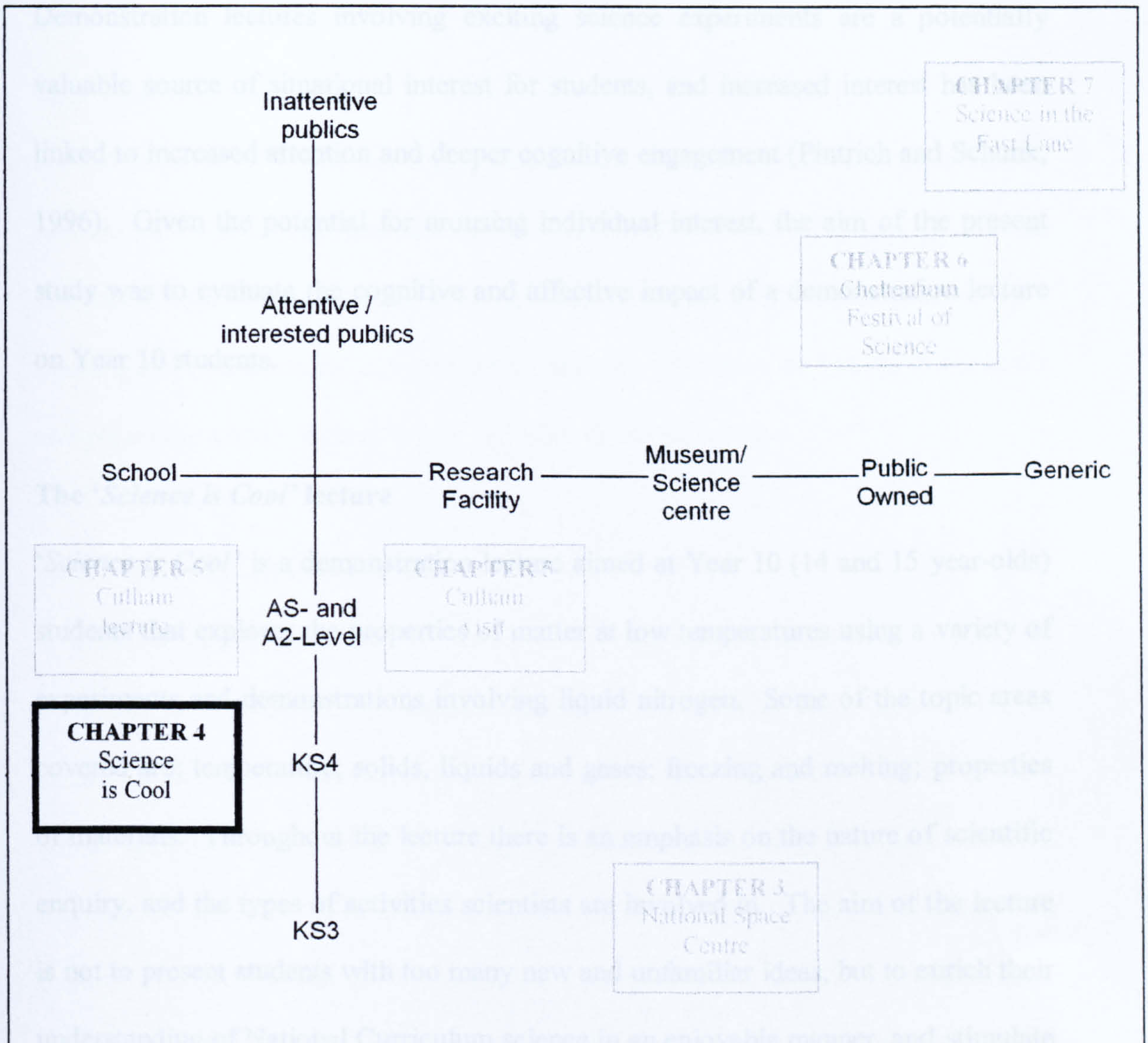
What did you think about the Space Centre and Planets show? Please write down why you thought this. Please write as much as you can.

Thanks!

Chapter 4

EVALUATION OF THE IMPACT OF A DEMONSTRATION LECTURE ON THE COGNITIVE AND AFFECTIVE DOMAINS OF KEY STAGE 4 STUDENTS

Research axes



Horizontal axis shows activity venue, vertical axis shows activity target audience

Chapter 4 is an evaluation of a liquid nitrogen demonstration lecture, '*Science is Cool'* on the cognitive and affective domains of Year 10 students. The lecture was delivered in schools to audiences of up to 280 students. The lecture was found to offer educational value, and attitudinal shifts were measured although some were more desirable than others. Students rated the lecture as enjoyable and teachers felt it was valuable for their students both in terms of education and enjoyment.

4.1 INTRODUCTION

Demonstration lectures involving exciting science experiments are a potentially valuable source of situational interest for students, and increased interest has been linked to increased attention and deeper cognitive engagement (Pintrich and Schunk, 1996). Given the potential for arousing individual interest, the aim of the present study was to evaluate the cognitive and affective impact of a demonstration lecture on Year 10 students.

The '*Science is Cool*' lecture

'*Science is Cool*' is a demonstration lecture aimed at Year 10 (14 and 15 year-olds) students that explores the properties of matter at low temperatures using a variety of experiments and demonstrations involving liquid nitrogen. Some of the topic areas covered are: temperature; solids, liquids and gases; freezing and melting; properties of materials. Throughout the lecture there is an emphasis on the nature of scientific enquiry, and the types of activities scientists are involved in. The aim of the lecture is not to present students with too many new and unfamiliar ideas, but to enrich their understanding of National Curriculum science in an enjoyable manner, and stimulate a fresh desire to learn. The lecture was developed by a Reader in physics at the University of Liverpool, and has been delivered to a range of school and public audiences.

4.2 METHODOLOGY

4.2.1 Lecture tour

For the purposes of the present study, a lecture tour was organised between April and June 2004. The lecture was delivered to audiences of 50 – 280 Year 10 science students at eight secondary schools in the Merseyside region. All of the schools were mixed gender community comprehensive schools. Students at five of the schools completed the questionnaires before and after the intervention.

4.2.2 Data collection materials

A questionnaire-based survey of students and teachers was conducted to measure indicators of attitudinal and cognitive change. The present study was similar in format to the study conducted in Chapter 3. It used closed-form questionnaires before and after the lecture to survey its impact on the cognitive and affective domains of students. Evaluation questions were included at the second stage to explore students' opinions of the lecture. Cognitive and affective impacts were measured both directly, using multiple-choice physics questions and attitudinal indicators, and indirectly by asking students to assess how much they felt they had learned, or if they felt their attitudes had changed. Teachers were also surveyed using open questionnaires, in order to establish their opinions of the intervention and the perceived impact on their students. The content and format of the questionnaires is described in more detail in Chapter 2, and copies of the questionnaires are provided in Appendix 4.1.

4.2.3 Piloting

The attitudinal tracking statements were those developed and tested by Spall (2005) and are described in more detail in Chapter 2. The questions for the knowledge quiz section of the questionnaires were piloted with 57 Year 10 students. Analysis of the results showed that the questions appeared to be at the correct level for the target audience. A copy of the pilot data results is given in Appendix 4.2.

4.3 RESULTS

4.3.1 The study cohort

Five of the eight schools involved in the tour completed the questionnaires before and after the lecture. A total of 491 students and 11 teachers took part in the present study. In order to reduce heterogeneity in the sample, responses from students who were not 14 or 15 years old, and who had not seen the presentation, were removed, leaving 460 students. The final study cohort is described in Figure 4.3.

Figure 4.3 *The study cohort*

Sample	*n*	*Age %*		*Gender %*	
		14	*15*	*Male*	*Female*
Student	460	24	76	49	51
Teacher	11	-	-	78	22

Of the teachers surveyed, two taught non-science subjects while nine taught science subjects. Of these nine, four taught physics.

4.3.2 Correlations between attitude, perceived ability and museum visits

Figure 4.4 shows associations between students' pre-existing attitudes towards physics and their perceived ability and frequency of visits to museums and science centres. The p values were obtained using Kendall's tau-b measure of association; the table presents both the correlation coefficients and the p values.

Figure 4.4 *Associations between attitude, perceived ability and museum visits*

	Rate physics ability as good		*Often visit museums and science centres*	
	τ	p	τ	p
Nature of the subject				
Like physics	0.54*	0.00	0.24*	0.00
Interesting	0.48*	0.00	0.28*	0.00
Boring	-0.42*	0.00	-0.19*	0.00
Relevant to everyday life	0.23*	0.00	0.16*	0.00
Academic demands of subject				
Easy	0.37*	0.00	0.04	0.38
Remembering facts rather than understanding ideas	-0.07	0.10	-0.05	0.21
Good at maths	-0.09*	0.04	0.13*	0.00
Types of student				
More a boys' subject	-0.06	0.14	-0.05	0.21
More a girls' subject	-0.04	0.30	-0.04	0.32
People who don't mix well	-0.13*	0.00	-0.10*	0.02
Communication of subject				
Uses lots of difficult words	-0.23*	0.00	-0.05	0.19
Uses everyday words with different meanings	0.12*	0.00	0.05	0.27

** Denotes correlation significant at the 95% level or above*

These associations indicate that students who rate their physics ability highly are likely to have positive opinions of the nature of the subject: they like physics, agree that it is interesting and relevant, and reject the notion that it is boring. The same is true for students who often visit museums and science centres. Unsurprisingly, students who perceive their physics ability as good were more likely to agree that physics is an easy subject. These students were more likely to reject the notion that mathematical ability was required for success in physics. The opposite association was observed for students who often visited museums; they were more likely to agree that mathematical ability was important. There was an association between students who thought their physics ability was good and those who felt physics used easy, and not difficult, language.

4.3.3 Impact of the lecture on students' affective domain

Figure 4.5 shows the responses to the attitudinal tracking questions before and after the lecture. The Wilcoxon ranking test was applied to explore significant shifts in the data. The percentages shown in Figure 4.5 merge the responses for '*strongly agree*' and '*agree*' under the '*affirm*' heading, and the responses '*strongly disagree*' and '*disagree*' under the '*reject*' heading. The statistical analysis was conducted on the data before the responses were merged, i.e. where responses were given on a 5-point scale.

Figure 4.5 Differences between responses before and after the lecture

	Before %			*After %*			*p*
	Affirm	*Neutral*	*Reject*	*Affirm*	*Neutral*	*Reject*	
Nature of the subject							
Like physics	36	33	31	37	30	34	0.94
Interesting	37	40	23	41	37	22	0.31
Boring	32	36	32	32	36	33	0.71
Relevant to everyday life	35	33	32	39	37	24	0.01*
Academic demands of subject							
Easy	9	34	58	10	36	54	0.13
Remembering facts rather than understanding	23	37	40	22	44	34	0.79
Good at maths	56	30	14	47	31	22	0.00*
Types of student							
More a boys subject	9	32	60	9	39	52	0.04*
More a girls subject	2	33	65	4	37	59	0.05*
People who don't mix well	8	22	71	12	25	63	0.00*
Communication of subject							
Uses lots of difficult words	36	38	26	36	43	21	0.65
Uses everyday words with different meanings	18	50	31	24	49	28	0.03*

** denotes a difference significant at the 95% level or higher*

Respondents were more likely to agree that '*the things I learn in physics relate to my everyday life*' after watching the lecture than beforehand and were significantly less likely to agree that mathematical ability was necessary for studying physics when questioned after the talk than before. Despite the fact that the lecturer was male, the responses to the questions regarding the gender bias of the subject were more similar after students had seen the lecture, with more students giving the neutral response to both questions the second time. There was a correlation between the gender of the students and their responses to the questions; the details are explored more fully in Chapter 8. Students were more likely to agree with the statement '*physics uses easy, everyday words with different meanings'* after watching the lecture. These results indicate a positive impact in the affective domain. However there was one negative shift in that students were more likely to agree that '*people who like physics don't mix very well with other people*' after seeing the lecture.

A small proportion of students (14%) felt that the lecture had changed the way they feel about physics. Nearly two-thirds (63%) felt the lecture had not changed their opinion, and the remaining 23% were not sure. To follow up this question, students were asked to describe the way in which their feelings about science had changed. Of the 62 responses, 60 were positive. Some of the students' comments on the way in which the lecture changed the way they feel about science are given below:

> *"Science can be useful and presented in a fun way"*
> (14 year-old female)
>
> *"I enjoy science more now and approach it in a different way"*
> (15 year-old male)
>
> *"I feel more excited about science"* (15 year-old male)
>
> *"More interesting to see the effects not read about it"*
> (15 year-old male)
>
> *"It makes me see that we can use physics in lots of things"*
> (14 year-old female)
>
> "*Science is amazing*" (15 year-old male)

Chi-square tests were used to examine whether students who reported a positive shift in attitude were those who liked or were interested in physics before the intervention. No significant associations between the variables were identified.

4.3.4 Impact of the lecture on students' cognitive domain

Figure 4.6 shows the percentages of students answering the knowledge test questions correctly and incorrectly before and after the lecture. The McNemar test was applied to the data to explore significant changes in responses to the questions.

Figure 4.6 Significant differences in responses before and after the lecture

Question	*% Correct Before*	*% Correct After*	*p*
Control – knowledge unrelated			
What is the chemical symbol for nitrogen?	66	66	0.57
Which of the following substances has the highest melting point?	72	67	0.03*
How many nitrogen atoms are there in a nitrogen molecule?	42	42	1.00
In which of the following substances are the particles furthest apart?	94	92	0.35
Lecture-related questions			
Approximately how much nitrogen is in the air around us?	55	61	0.01*
Which of the following is the correct unit for density?	61	62	0.62
Which of the following is ***not*** a reversible change?	81	81	1.00
What is the name of the process of a gas changing to a liquid?	87	88	0.62
What temperature is absolute zero?	40	58	0.00*
Which of the following is most likely to slow down a chemical reaction?	64	65	0.60

** denotes a difference significant at the 95% level or higher*

Two of the questions relating to material covered in the lecture showed a significant improvement in knowledge. It appears that two of the other questions relating to the lecture were too easy, over 80% of the students answered correctly before the lecture, leaving little room for improvement. This was not the case in the pilot study, as can be seen from the results in Appendix 4.2. One of the control questions demonstrated a negative shift in knowledge. The question was '*Which of the following has the highest melting point?*' and the possible responses were: '*Water*', '*Nitrogen*', *Wax*', and '*Aluminium*'. Some 20% of students answered '*Nitrogen*' before the lecture, and 24% responded this way after the lecture. This could be related to the fact that the lecture involved liquid nitrogen, so students assumed that this was the correct response.

Students perceived the lecture as educational, a large majority (94%) felt they had learned at least '*a little*' science from the lecture, while 59% felt they had learned at least '*some*' science and 12% felt they had learned '*a lot*' of science.

> *"I learnt something new and it was fun while learning it"* (15 year-old female)
>
> *"It was good, and interesting and a fun way to learn"* (15 year-old male)
>
> *"I think that these presentations should take place about twice a week because I found out that I learned more and remembered more"* (15 year-old female)

4.3.5 Evaluation of lecture by students

The majority of students (81%) who saw the presentation felt it was interesting, and a similar proportion (83%) felt that the scientific level of the lecture was '*about right*'. Two thirds of students (66%) rated the length of the lecture as '*about right*', but a quarter (26%) felt it was '*too long*'. Most students (80%) were satisfied with the pace of the lecture.

4.3.6 Students' impressions of the lecture

Students were asked to write down three words that described their impressions of the lecture. The 1106 responses from 429 students were grouped into categories. ***Positive*** responses expressed a generally positive reaction to the talk, and responses in the ***negative*** category contained generally negative statements. Students described the lecture with words and phrases indicating they had found it ***interesting*** or ***boring***, and many responses described the show as ***entertaining***. Some responses indicated a ***neutral*** response to the lecture, for example 'average'. Some students remarked on the ***educational*** value of the lecture, and some described it as ***different***. Responses indicating that the lecture was ***too long*** or ***too slow*** have been categorised together. A number of responses included reference to the ***content*** of the lecture, often the scientific content. Responses that fell in none of the above categories were grouped in the ***other*** category. The results of the category analysis are summarised in Figure 4.7.

Figure 4.7 *Students' impressions of the lecture*

Category	*Number of responses*
Positive	265
Interesting	257
Entertaining	245
Negative	58
Different	53
Educational	51
Too long/too slow	48
Neutral	45
Boring	34
Content	33
Other	18

These data show that most responses (69%) indicated a positive impression of the lecture. There were many responses describing the lecture as interesting and entertaining, although some students found it boring.

Students were more likely to perceive the talk in an entertainment or interest context than an educational one. The evaluation section of the questionnaire also gave students the opportunity to leave unstructured feedback by asking them to provide any additional comments. Responses included:

> *"It made me think that they must do fun stuff at university, not just lectures"* (15 year-old female)
>
> *"The liquid nitrogen stuff was good when you did the experiments, but all the rest was boring"* (14 year-old male)
>
> *"I feel that the presentation should of* [sic] *lasted for two lessons so that we learnt more!"* (15 year-old male)
>
> *"It was quite good but I still don't like science very much"* (15 year-old male)
>
> *"There were too many people in the hall so I couldn't see the presentation which made it far too long"* (14 year-old female)

4.3.7 Evaluation of lecture by teachers

All eleven teachers rated the lecture as '*interesting*' or '*very interesting*', with just over half (six) rating it as the latter. Most felt the length of the lecture was '*about right*' although two felt it was '*too long*'; one of these qualified the response by commenting that the lecture took place on a hot afternoon and the students were restless as a result. All of the teachers surveyed agreed that the lecture was pitched at an appropriate scientific level. All but two teachers felt the lecture offered educational value for their students. The survey asked if the teachers felt that a lecture such as this was an effective means of communicating science to their students. Four respondents mentioned the visual nature of the lecture as a positive aspect here, one with a specific reference to its appeal to visual learners. Three respondents referred implicitly to the situational interest generated by the lecture:

> *"Many visual learners may be inspired"* (female history teacher)

"They always respond to an outside visitor and love new things" (male chemistry teacher)

"Any external influence is likely to be positive. Lively presentation is likely to stick with them" (male physics teacher)

All of the teachers agreed that the lecture was an enjoyable way of presenting science to their students, and three commented that students had spoken about their positive opinions of the lecture during subsequent lessons.

4.4 DISCUSSION

4.4.1 Summary of results

Overall, students responded well to the lecture, with many describing it as interesting and entertaining. Several attitude shifts were indicated, although the design of the study means these represent a short-term impact. It is unclear whether the shift in attitude would be sustained over the medium and long term. The lecture was shown to have some impact on students' factual knowledge; the measurement of this could have been improved, however. Teachers rated the lecture highly. When probed about why the lecture was a positive experience for students, teachers' responses included references to the lecture's visual nature and the fact that it was something '*different*', indicating that the situational interest generated by the lecture may contribute to its impact on students.

4.4.2 Affective impact

The most interesting shift in student attitude was that they were more likely to agree that physics holds relevance to everyday life after watching the lecture than beforehand. Although liquid nitrogen is not in itself an everyday substance, the experiments in the lecture were often related to experiences that would be familiar to students, for example the way in which refrigerators use low temperatures to slow down the chemical reactions that cause food to rot. This finding is reinforced by several of the students' quotes in which they reported that they could see how science related to everyday life. Students were also less likely to perceive physics as either a 'boys' or 'girls' subject following the lecture, which was an interesting finding since no explicit references to gender were included in the lecture. This shift is explored in more detail in Chapter 8, where the impact of different interventions on males and females is considered.

Students were more likely to agree that the language used in physics was easier following the lecture. This is likely to be due to the lecturer's experience in communicating with these groups – his awareness of National Curriculum content meant that little technical terminology was used during the lecture, and any such terms were introduced with an appropriate explanation. This finding highlights the importance of the presenter's role in an intervention such as this; had the presenter not pitched the language at the right level scientifically this shift could have been negative as opposed to positive. There was one negative change in attitude; students were more likely to agree that '*people who like physics don't mix very well with others*'. This, again, may have been related to the presenter of the lecture, a Reader in Physics at the University of Liverpool, substantially older than the target audience. The presentation of the lecture was in the style of an enthusiastic scientist, which clearly entertained the audience (according to the evaluation data), but was perhaps not the role model that the target audience would identify with.

Responses to the evaluation questions indicated that the lecture had generated a high level of situational interest in the students, and that this had led some to reckon their attitude towards the subject had shifted, and indeed the quantitative data bore this out. In order to maximise the impact of an intervention such as this, ways in which engagement with the intervention can be extended and maximised should be explored in order to increase the probability of this situational interest developing into the longer-term individual interest.

4.4.3 Cognitive impact

Significant positive cognitive shifts were measured for two of the six lecture-dependant tracking questions. Shifts may have been measured for other questions if the difficulty level of the questions had been higher; for two of the questions over 80% of students answered correctly the first time so there was little room for improvements to be measured. This could be improved if a similar study were to be repeated.

Students perceived the lecture as educational; a large majority felt they had learned some science from the lecture, and a number described the lecture as educational in the open questionnaire responses. The frequency of responses in the educational category was, however, considerably lower than the number of responses that described the lecture as interesting or fun. This indicates that students perceived the intervention in terms of its entertainment and interest value ahead of any educational value. Interestingly, several students commented on preferring the lecture to lessons, due in part no doubt to time pressures in lessons and stringent health and safety regulations meaning that liquid nitrogen demonstrations are rarely carried out in the classroom. Students made a few references to different learning styles, with comments that watching demonstrations was a more interesting way to learn than, for example, reading. Using interventions such as the demonstration lecture can help broaden the range of teaching styles employed in a school, allowing science to appeal to students with a variety of learning styles and preferences. Some students also commented that they learned better this way, and that they would remember more science. Teachers expressed similar sentiments, feeling that the lecture was educationally valuable for the students, and an effective means of communicating science to them.

Although the students appeared to respond positively to the lecture, the impacts measured were not as strong as those measured for the National Space Centre visit in Chapter 3. This could be due to the nature of the different activities or a function of the target audience or, most likely, a combination of these and other factors. The next study was designed to explore the influence of taking students out of the classroom, and evaluates the impact of both a lecture and a visit on AS- and A2-Level Physics students.

Appendix 4.1

Data collection materials

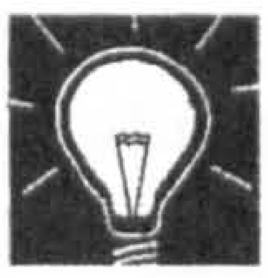
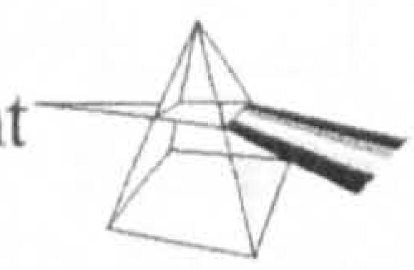
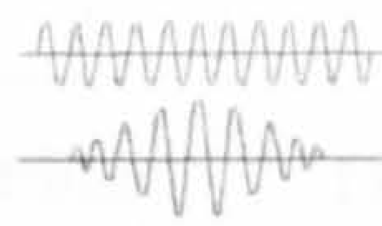
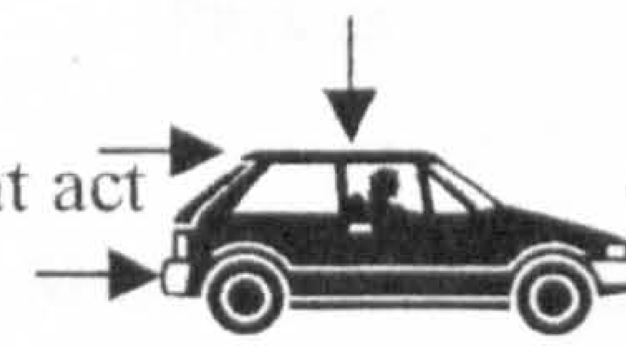
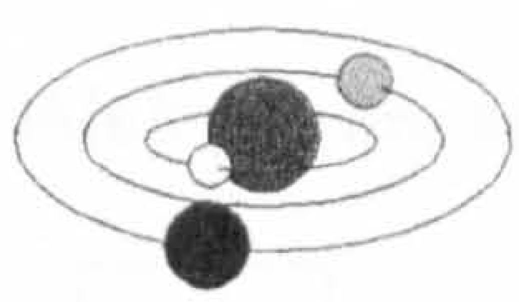
- Student questionnaires, pre- and post-intervention (NB attitudinal questions and quiz questions were identical at both stages – these pages of the questionnaire are only included once)

- Teacher questionnaires

Physics Questionnaire

We are doing a big study to see what people think of some of their school subjects, like Science. We are especially interested in what you think about Physics.

Physics is about all of the below:

- Electricity  and circuits
- The way light  and sound work and travel 
- Gravity and other forces that act  on things and how things move
- Magnets  and electric motors
- Space, stars  and planets

Now for the questions...

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname..............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

☐	☐	☐	☐	☐
I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics

Outside school, do you ever visit Museums or Science Centres?

☐	☐	☐	☐	☐
Lots of Times	Often	Sometimes	Very Occasionally	Never

How good do you think you are at Physics?

☐	☐	☐	☐	☐
Really Good	Quite Good	About Average	Quite Bad	Really Bad

KS4SiC/PRE

These questions are about Physics

Physics is an **interesting** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

You need to be **good at maths** to do physics

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more of a **boys** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is a **boring** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more to do with **remembering facts** than understanding ideas

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

The things I learn in physics **relate to my everyday life**

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

People who really like physics **don't mix very well** with other people

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more of a **girls** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **difficult, complicated** words

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is an **easy** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **easy, everyday words** but with a **different meaning**

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Quick Quiz

All of the following questions are about Physics. Answer the questions by ticking the box that you think is the right answer.

Here is an example of how to answer the questions:

Which of the following television soap operas is about life in Liverpool?

Eastenders	☐	Coronation Street	☐
Brookside	✓	Neighbours	☐

And now for the quiz...

What is the chemical symbol for Nitrogen?

Ni	☐	N	☐
n	☐	NT	☐

Approximately how much Nitrogen is in the air around us?

10%	☐	25%	☐
50%	☐	75%	☐

Which of the following substances has the highest melting point?

Water	☐	Nitrogen	☐
Wax	☐	Aluminium	☐

Which of the following is the correct unit for density?

Kilograms per metre squared (kg/m^2)	☐	Kilograms per metre cubed (kg/m^3)	☐
Metres per kilogram (m/kg)	☐	Kilograms squared per metre (kg^2/m)	☐

How many Nitrogen atoms are there in a Nitrogen molecule?

1 ☐	2 ☐
3 ☐	4 ☐

In which of the following substances are the particles furthest apart?

Metal ☐	Air ☐
Wood ☐	Orange juice ☐

Which of the following is ***not*** a reversible change?

Denaturing an enzyme ☐	Ice melting ☐
Dissolving salt in water ☐	Heating the air in a room ☐

What is the name of the process of a gas changing to a liquid?

Evaporation ☐	Condensation ☐
Perspiration ☐	Sublimation ☐

The lowest possible temperature is called ***Absolute Zero***. Which of the following is it?

-115°C ☐	-196°C ☐
-273°C ☐	-998°C ☐

Which of the following is most likely to slow down a chemical reaction?

Adding a catalyst ☐	Increasing reactants' surface area ☐
Reducing the temperature ☐	Increasing reactant concentration ☐

School Talk Questionnaire

We are doing a big study to see what people think of some of their school subjects, like Physics. We would also like to know your opinions on the presentation "Science is Cool".

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics
☐	☐	☐	☐	☐

KS4/SiC/POST

These Questions are about the Presentation "Science is Cool"

Did you see the "Science is Cool" Liquid Nitrogen presentation?

☐ Yes ☐ No

What did you think of the presentation?

☐ Very Interesting ☐ Interesting ☐ Neither Interesting nor Boring ☐ Boring ☐ Very Boring

What did you think of the length of the presentation?

☐ Much Too Long ☐ Too Long ☐ About Right ☐ Too Short ☐ Much Too Short

What did you think of the pace (speed) of the presentation?

☐ Much Too Fast ☐ Too Fast ☐ About Right ☐ Too Slow ☐ Much Too Slow

What did you think about the Science in the presentation?

☐ Much Too Easy ☐ Too Easy ☐ About Right ☐ Too Difficult ☐ Much Too Difficult

What did you think of the presentation slides?

☐ Very Good ☐ Good ☐ Neither Good Nor Bad ☐ Bad ☐ Very Bad

How much Science do you think you learned from the presentation?

☐ A Lot ☐ Some ☐ A Little ☐ None

Tell us three words that you would use to describe the presentation:

Do you think that the presentation has changed the way you feel about Science?

☐ Yes ☐ No ☐ Don't Know

If YES, in what way?

If you have any other comments about the presentation, please write them in the box below. Please write as much as you can:

Thanks!

Teacher Questionnaire

We are interested in your thoughts about the **Science is Cool** presentation.

Please take a few moments to complete this questionnaire - your comments will help us tailor future events to your needs.

Firstly, some information about yourself...

School ....

Which subject do you teach?...

Student Year group involved in presentation..

Male/Female ....

These questions are about the Presentation

Did you see the "Science is Cool" Liquid Nitrogen presentation?

Yes	No
☐	☐

What did you think of the presentation?

Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring
☐	☐	☐	☐	☐

What did you think of the length of the presentation?

Much Too Long	Too Long	About Right	Too Short	Much Too Short
☐	☐	☐	☐	☐

Do you think that the presentation was at the right level for your students? If not, in what way?

Do you think that your students learned much Science from the presentation?

Do you think that a presentation such as this is an effective means of communicating Science to your students? Why?

Do you think that the talk was enjoyable for your students? Why?

What were your aims and expectations for the talk?

Have your aims been fulfilled? Why?

If you have any other comments about the presentation, please write them below.

Thanks!

KS4/SiC/TEACHER

Appendix 4.2

Pilot study results for knowledge quiz questions

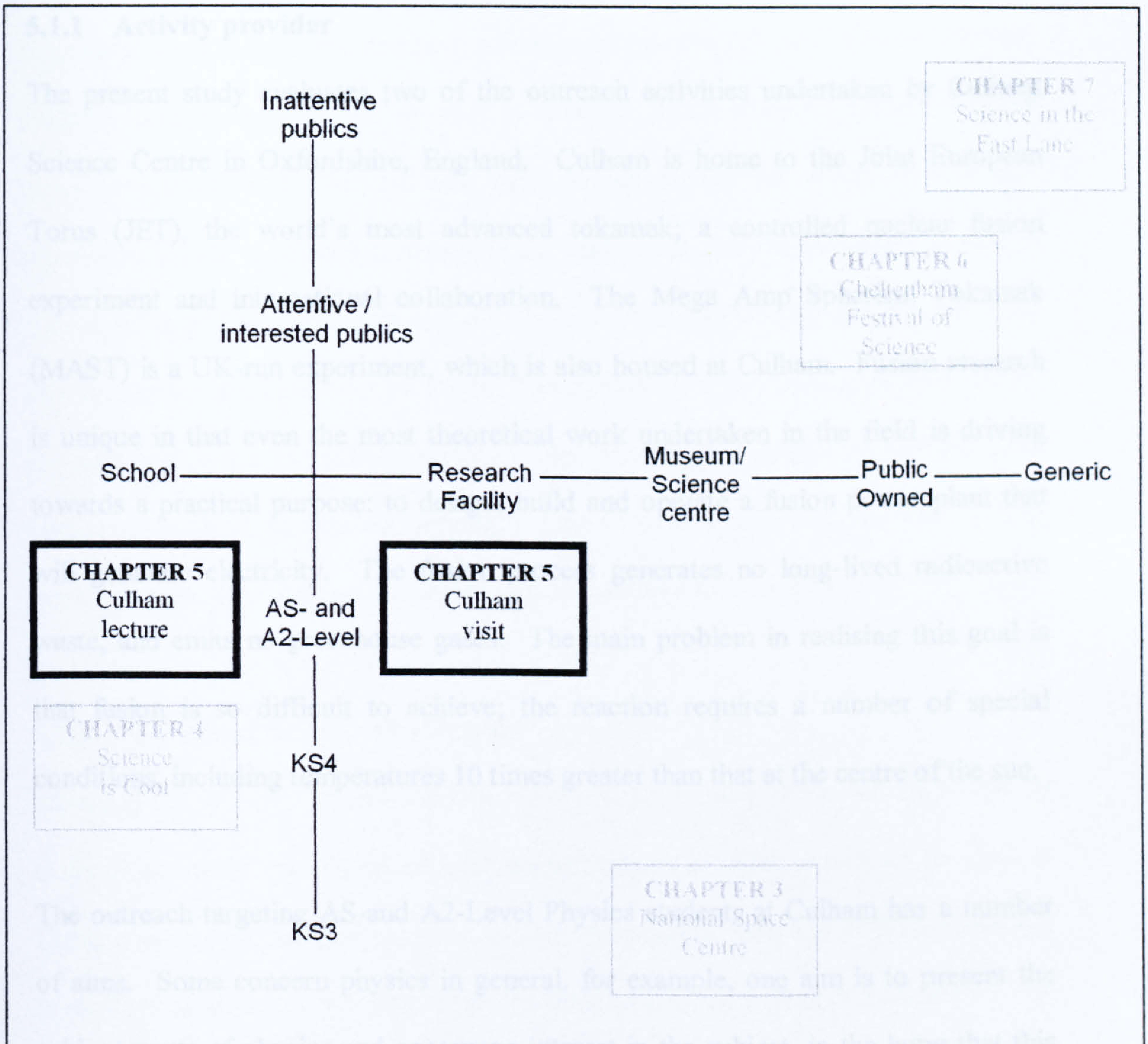
Question	*% Correct*
Control – knowledge unrelated	
What is the chemical symbol for nitrogen?	52
Which of the following substances has the highest melting point?	44
How many nitrogen atoms are there in a nitrogen molecule?	27
In which of the following substances are the particles furthest apart?	91
Lecture-related questions	
Approximately how much nitrogen is in the air around us?	26
Which of the following is the correct unit for density?	36
Which of the following is ***not*** a reversible change?	64
What is the name of the process of a gas changing to a liquid?	66
What temperature is absolute zero?	13
Which of the following is most likely to slow down a chemical reaction?	36

The pilot was conducted at the same point in the school year as the main data collection exercise. The highest percentage of correct answers for the lecture-dependent questions was 66%.

Chapter 5

EVALUATION OF THE COGNITIVE AND AFFECTIVE IMPACT OF OUTREACH ACTIVITIES ON AS- AND A2-LEVEL PHYSICS STUDENTS

Research axes



Horizontal axis shows activity venue, vertical axis shows activity target audience

In Chapter 5, the impacts of two outreach activities from Culham Science Centre are evaluated. A lecture, '*Great Balls of Fire*', given in schools, was compared with the a visit to the facility incorporating a similar lecture and a tour of the site. Unfortunately, a poor sample size for the visit intervention meant that the results proved inconclusive. The evaluation of the lecture, however, indicated that it has a strong cognitive impact. Measuring affective impact was more difficult, partly because most respondents had pre-existing positive attitudes towards physics.

5.1 INTRODUCTION

5.1.1 Activity provider

The present study evaluates two of the outreach activities undertaken by Culham Science Centre in Oxfordshire, England. Culham is home to the Joint European Torus (JET), the world's most advanced tokamak; a controlled nuclear fusion experiment and international collaboration. The Mega Amp Spherical Tokamak (MAST) is a UK-run experiment, which is also housed at Culham. Fusion research is unique in that even the most theoretical work undertaken in the field is driving towards a practical purpose: to design, build and operate a fusion power plant that will generate electricity. The fusion process generates no long-lived radioactive waste, and emits no greenhouse gases. The main problem in realising this goal is that fusion is so difficult to achieve; the reaction requires a number of special conditions, including temperatures 10 times greater than that at the centre of the sun.

The outreach targeting AS-and A2-Level Physics students at Culham has a number of aims. Some concern physics in general, for example, one aim is to present the achievements of physics and encourage interest in the subject, in the hope that this may encourage more students to consider a career in physics. More specifically, the activities aim to inform students of the merits and status of fusion research, with a view that students are the voters and decision-makers of the future. Finally, such activities aim to de-mystify the work undertaken at Culham, and perhaps encourage students to consider a future career at the facility.

5.1.2 Outreach activities at Culham Science Centre

In order to meet these aims, outreach activities targeted at AS- and A2-level Physics students have been developed by staff at Culham. Such activities include lectures given in schools and other venues, visits to the facility for school groups and interactive stands at science festivals. This study considers the impact of a lecture, *'Great Balls of Fire'*, given in schools and a visit to Culham Science centre. The visit comprises a shorter version of the *'Great Balls of Fire'* lecture, an opportunity for questions and a tour of the facility. The present study primarily evaluated the impact of lectures in schools, although data were also collected for visits. The impact of these two outreach activities will be compared where possible.

5.1.3 The *'Great Balls of Fire'* lecture

'Great Balls of Fire' is an hour-long presentation about nuclear fusion, given by Culham Science Centre's education outreach manager, who previously worked at Culham as an experimental physicist. The presentation, aimed at both AS- and A2-level Physics students, sets the scene for fusion research, in which imminent world population increase and dwindling fossil fuel supplies mean that the need for new power sources is more pressing than ever. The talk explains the fusion research at Culham. It describes how physicists and engineers from many countries are working to design and build the first fusion power plant, and that success will make an enormous change in the way that electricity is generated. This presentation covers material in the (optional) nuclear physics section of the A2-level syllabus, and provides an insight into the type of work conducted by physicists and engineers. The presentation was *PowerPoint*-based and also used a plasma ball and magnet

demonstration as visual aids. Eight talks were evaluated over a period of one year, in eight different schools. Audience sizes for the talk varied from 15 to 80.

5.1.4 Visits to Culham Science Centre

Visits to Culham Science Centre comprise a talk and a tour. The talk is very similar to *'Great Balls of Fire'*, and is usually (although not always) presented by the same person. It is however, slightly shorter in length. For the tour, students wear hard hats and are taken around the extensive Culham site. The control rooms for JET and MAST are visited, as well as the JET torus hall if possible (depending on work being undertaken at the time of the visit). Students watch video recordings of a plasma inside MAST and the robotics used to maintain the JET torus are explained. Students have opportunities to ask questions of the speaker and the guides throughout the visit. Guides are usually physicists and engineers who volunteer to help with the visits, so students hear about the research from those actively involved. Guides receive some training from the education team. Five visits were evaluated over a period of about one year; numbers attending ranged from 4 to 20.

Informal feedback from students and teachers to the education team at Culham had indicated that the visits had a greater impact than the lectures delivered in schools. However, there are restrictions on the number of students who can participate in such visits. For example, it is possible for a maximum of only 20 students to visit Culham at one time, and there is a limit on the amount of time the volunteer guides can offer. Also, due to security issues on all United Kingdom Atomic Energy Authority (UKAEA) sites (of which Culham is one) the administration that accompanies each visit is considerable. Furthermore, in order to take students out of school, teachers must obtain written consent from parents or guardians, and one adult must accompany every 10 students on a visit. Add the cost of extra cover to the price of hiring a coach and the visit soon becomes very expensive for the school, despite there being no charge from Culham. This situation creates a dilemma; visits are perceived by Culham staff to have a greater impact but reach fewer students and are expensive in terms of time and money both for schools and Culham. Lectures, on the other hand, reach more students, are free for schools and only require the time of one Culham staff member; however their impact is perceived as less great. This study aims to explore, in a more formal manner, the impact of each outreach activity on the cognitive and affective domains of students involved.

5.2 METHODOLOGY

5.2.1 Survey of students

The present study used a similar methodology to the studies conducted in Chapters 3 and 4. Closed-form before-and-after questionnaires were used to survey changes in students' attitudes towards and understanding of physics. Evaluation questions also surveyed students' opinions of the lecture and tour. The first stage questionnaires were administered in the week before the talk or visit, and the second stage questionnaires were administered in the week following the intervention. Questionnaires were piloted with 20 students who visited Culham Science Centre. A copy of the questionnaires used is given in Appendix 5.1

5.2.2 Survey of teachers

Teachers were asked to complete a short open questionnaire after the lectures and visits. This questionnaire had two aims; firstly to collect teachers' opinions of the intervention; and secondly to use teachers as a means of gauging the impact of the talks and visits on their students. A copy of the teachers' questionnaire is provided in Appendix 5.2.

5.3 RESULTS

5.3.1 The study cohort

A total of 261 students from eight schools took part in the study evaluating the lecture. Some 45 students from three schools and two summer schools took part in the study evaluating the visit. The summer school students were on a course held during the July following their GCSEs, so they are not strictly AS- or A2-level students, and had not necessarily elected to study physics. Summer school students accounted for 18 students from the visit sample. Ten teachers and one learning assistant were also surveyed following the lecture. Unfortunately, no teacher data was obtained for the visit. A summary of the sample demographics is given in Figure 5.1 below:

Figure 5.1 *The study cohort*

Sample	*n*	*Age %*				*Gender %*	
		16	**17**	**18**	**19**	**male**	**female**
Lecture	261	19	52	28	1	82	18
Visit	45	42	18	29	11	53	47
Teacher	11	n/a	n/a	n/a	n/a	50	50

The mean age of the visit sample is lower than that of the lecture sample. This probably reflects the fact that the visit data were collected over a period of approximately 18 months, while most of the lecture data were collected during May/June 2004, the end of the school year. This explains why there are relatively few 16-year-old students in the lecture sample. The lecture sample is more male-dominated than the visit sample. This may be because of the schools included in the lecture tour, several of which were boys' schools (although one of which was a girls' school). Organising a lecture tour for mixed gender comprehensive schools was attempted, however, this proved difficult. No schools requested the lecture, and when reasons for this were explored it was found that many of the schools contacted had a low AS- and A2-Level Physics uptake, and felt that the audience size they could provide for such a lecture would be too small. Two alternatives were proposed, either organising lectures at one school or at the University of Liverpool and inviting other schools to attend, or relaxing the criteria for schools to be included in the study. Since the purpose of the study was to probe the relationship between the lecture venue and its impact, it was felt that organising lectures in alternative venues would confuse the results. For this reason, single sex and non-comprehensive schools, who would not normally be included in research of this nature, were contacted and offered the lecture in exchange for inclusion in the study. This allowed a reasonable sample size for the lecture to be obtained.

5.3.2 Associations between attitude, perceived ability and museum visits

Figure 5.2 shows associations between students' pre-existing attitudes towards physics, their perceived ability and frequency of visits to museums and science centres. The table includes data from students in both the lecture and the visit samples. The p values were obtained using Kendall's tau-b measure of association; the table presents both the correlation coefficients and the p values.

Figure 5.2 Associations between attitude, perceived ability and museum visits

	Rate physics ability as good		***Often visit museums and science centres***	
	τ	*p*	τ	*p*
Nature of the subject				
Like physics	0.43*	0.00	0.18*	0.00
Interesting	0.35*	0.00	0.19*	0.00
Boring	-0.29*	0.00	-0.19*	0.00
Relevant to everyday life	0.15*	0.00	0.09	0.07
Academic demands of subject				
Easy	0.42*	0.00	0.11*	0.03
Remembering facts rather than understanding ideas	-0.26*	0.00	-0.03	0.52
Good at maths	-0.02	0.72	0.00	0.97
Types of student				
More a boys subject	-0.02	0.62	-0.12*	0.02
More a girls subject	-0.03	0.52	-0.02	0.76
People who don't mix well	-0.12*	0.02	-0.11*	0.03
Communication of subject				
Uses lots of difficult words	-0.13*	0.01	-0.03	0.52
Uses everyday words with different meanings	0.42*	0.00	0.04	0.48

** denotes association significant at the 95% confidence level or above*

These data indicate that students who rate their physics ability highly are more likely to enjoy the subject, find it easy and think physics students mix well with other people. Students who often visit museums and science centres outside school are also more likely to have a positive attitude towards physics and find it interesting.

5.3.3 Impact of the lecture

Impact of the lecture on students' affective domains

Figure 5.3 shows students' responses to the attitudinal tracking statements before and after the lecture. The p values were obtained using The Wilcoxon signed ranks test.

The percentages shown in the table below merge the responses for '*strongly agree*' and '*agree*' under the '*affirm*' heading, and the responses '*strongly disagree*' and '*disagree*' under the '*reject*' heading. The statistical analysis was conducted on the data before the responses were merged, i.e. where responses were given on a 5-point scale.

Figure 5.3 ***Differences between responses before and after the lecture***

	Before %			*After %*			*p*
	Affirm	*Neutral*	*Reject*	*Affirm*	*Neutral*	*Reject*	
Nature of the subject							
Like physics	82	13	5	84	12	4	0.70
Interesting	89	8	3	88	9	3	0.05*
Boring	8	20	73	8	20	72	0.54
Relevant to everyday life	49	29	22	51	30	20	0.40
Academic demands of subject							
Easy	13	26	61	14	33	54	0.01*
Remembering facts rather than understanding	10	17	73	12	31	57	0.00*
Good at maths	74	19	7	64	27	9	0.00*
Types of student							
More a boys subject	22	41	37	23	40	38	0.95
More a girls subject	0	34	66	2	36	62	0.20
People who don't mix well	7	18	75	9	17	74	0.03*
Communication of subject							
Uses lots of difficult words	16	37	47	23	41	36	0.00*
Uses everyday words with different meanings	19	43	37	23	46	31	0.05*

** denotes difference significant at the 95% confidence level or above*

The results show that there was a slight negative shift in finding physics interesting following the lecture. However, this may be due to the fact that such a high proportion of the students in the cohort agreed that physics was an interesting subject before the lecture (56% agree, 32% strongly agree). There was little space remaining on the scale for these students to register an increased interest, and consequently perhaps only negative shifts were registered. Students were significantly less likely to agree that mathematical ability was necessary for studying physics after the talk than before, although they were more likely to agree that physics requires more factual recall than understanding after watching the lecture. Responses under the communication of subject theme were contradictory, with some students more likely to agree that physics uses *'difficult words'* after seeing the lecture, and some students more likely to agree that the language employed to communicate the subject was easy. It appeared that students were less likely to reject the idea that physics is easy following the lecture.

Students were asked whether the lecture had changed the way they felt about physics. Most (73%) said no, while 14% said yes and the remaining 13% were unsure. If they responded in the affirmative, students were asked to describe the nature of the change.

> *"brought it to life, how it can be used for important things"*
> (18 year-old male)
>
> *"I find it more interesting but still hard"* (17 year-old male)
>
> *"made me want to learn more about fusion"* (17 year-old male)

Impact of the lecture on students' cognitive domains

Figure 5.4 shows the proportions of students answering the knowledge quiz questions correctly before and after the visit. McNemar's test for differences was applied to calculate the p values displayed in the table.

Figure 5.4 Differences in responses before and after the lecture

Question	*% Correct*		*p*
	Before	*After*	
Control – knowledge unrelated			
Which of the following is not a form of electromagnetic radiation?	89	85	0.19
Which of the following is a renewable energy source?	99	98	0.45
What is the name of the fusion reactions that occur in the sun?	27	32	0.16
Which law of physics halts the collapse of a large dying star?	39	43	0.31
Lecture-related questions			
What is a Tritium nucleus made up from?	81	86	0.12
Which country uses most energy per person in the world?	91	95	0.09
Which of the following is not an advantage of fusion power?	58	80	0.00*
Where is Deuterium extracted from?	60	90	0.00*
Which of the following has reached the highest temperature?	26	69	0.00*
Which of the following is an everyday example of a plasma?	72	91	0.00*

** denotes difference significant at the 95% confidence interval or higher*

Four out of the six questions relating to material covered in the lecture showed improved responses following the presentation. None of the control questions showed a statistically significant difference in response before and after the lecture, however for two of these the initial responses were mostly correct. This was also the case for two of the lecture-related questions. The most significant shift in the aspects of knowledge that were measured was for the question: '*which of the following has reached the highest temperature?*' The four possible answers were: *a boiling kettle; the centre of the sun; the JET plasma; a light bulb filament.* Most students (72%) answered '*the centre of the sun*' (incorrect) before the intervention, compared with 30% afterwards.

Students were asked how much physics they felt they had learned from the lecture. Around a tenth (11%) said they had learned *'a lot'*, 54% said they had learned *'some'*, 30% said they had learned *'a little'* and 5% said they had learned *'none'*.

Students' evaluation of the lecture

Most students (87%) felt that the *'Great Balls of Fire'* lecture was interesting. The length of the talk and the pace were also judged to be *'about right'* by the majority of students (82% and 91% respectively). Four fifths (80%) rated the slides as *'good'*, and three quarters (76%) felt that the talk was pitched at the right level scientifically. Overall it appears that the talk was well suited to the target audience:

> *"makes people realise that physics can have a major effect on everyday instead of just being related to questions in a textbook"*
> (17 year-old male)
>
> *"it was a great talk. Thank you!"* (17 year-old female)
>
> *"very interesting and pitched exactly at our level (A2)"*
> (18 year-old male)

Some students had ideas for how to improve the lecture, these included more visual aids and perhaps some video clips of *'JET in action'*.

5.3.4 Impact of the visit

Impact of the visit on students' affective domains

Figure 5.5 shows students' responses to the attitudinal tracking statements before and after the visit to Culham Science Centre, which incorporated a tour of the facility and a lecture similar to *'Great Balls of Fire'*. The p values were obtained using The Wilcoxon signed ranks test. As with the data from the lecture sample, the 5-point responses were merged to 3 points for presentation in the table but not for the statistical analysis.

Figure 5.5 *Differences in responses before and after the visit*

Statement	*Before %*			*After %*			*p*
	Affirm	*Neutral*	*Reject*	*Affirm*	*Neutral*	*Reject*	
Nature of the Subject							
Like physics	64	20	16	67	13	20	0.71
Interesting	75	16	9	77	11	11	0.24
Boring	12	28	61	12	14	74	0.21
Relevant to everyday life	61	23	16	61	26	14	0.81
Academic demands of subject							
Easy	7	44	49	16	37	47	0.15
Remembering facts rather than understanding	14	28	58	14	44	42	0.07
Good at maths	72	21	7	58	33	9	0.06
Types of student							
More a boys subject	26	30	44	19	33	49	0.20
More a girls subject	2	28	70	0	37	63	0.47
People who don't mix well	2	26	72	7	19	74	0.60
Communication of subject							
Uses lots of difficult words	33	28	40	21	44	35	0.70
Uses everyday words with different meanings	16	61	23	19	56	26	1.00

None of the differences in responses before and after the visit were strong enough to reach statistical significance, perhaps because they are weak, or perhaps because the sample size was small. However, there appear to be some trends in the data, for example, fewer students agreed that mathematical ability is important for physics after the visit, and more students agreed that physics is an easy subject following the visit. These did not reach the level of statistical significance.

Again, students were asked if they felt that the visit had changed the way they felt about physics. The results were very similar to those for the lecture sample. The majority (74%) said '*no*', some (15%) said '*yes*' and the remainder (12%) were unsure. If students responded that the intervention had changed the way they felt about physics, they were asked to describe the nature of the change. Some responses are given below:

> *"it was just a really cool atmosphere: so much science, and wires, and probes etc like going into space"* (19 year-old male)
>
> *"made me interested"* (16 year-old female)

Impact of the visit on students' cognitive domains

Figure 5.6 shows the percentages of students answering the knowledge quiz questions correctly and incorrectly before and after the lecture. The p values were calculated using McNemar's test for differences, as described in Chapter 2.

Figure 5.6 *Differences in responses before and after the visit*

Question	*% Correct*		*p*
	Before	*After*	
Control – knowledge unrelated			
Which of the following is not a form of electromagnetic radiation?	80	88	0.25
Which of the following is a renewable energy source?	98	98	1.00
What is the name of the fusion reactions that occur in the sun?	50	50	1.00
Which law of physics halts the collapse of a large dying star?	46	51	0.79
Lecture-related questions			
What is a Tritium nucleus made up from?	81	95	0.03*
Which country uses most energy per person in the world?	95	98	1.00
Which of the following is not an advantage of fusion power?	64	77	0.13
Where is Deuterium extracted from?	73	85	0.13
Which of the following has reached the highest temperature?	37	88	0.00*
Which of the following is an everyday example of a plasma?	71	88	0.04*

* *denotes significance measured at the 95% confidence interval or higher*

It is interesting that, again, there is a statistically significant shift in knowledge for the question: '*which of the following has reached the highest temperature?*' as this question addressed a misconception held by students. Most respondents (61%) answered '*the centre of the sun*' (incorrect) before the visit, while only 10% gave this answer afterwards. There was also a statistically significant improvement in the aspects of knowledge relating to the tritium nucleus and plasma example. Interestingly, there was no shift measured for the tritium nucleus question following the lecture. This may be a result of one aspect of the tour emphasising this information. Trends in the data appeared to show that students were more likely to answer the related questions correctly after the visit than before, however these trends did not reach statistical significance. Again, this may be due to the trends being weak or the sample size being small.

Students were asked how much physics they felt they had learned from the visit. Again the results were similar to those from the lecture sample, although all of the students who took part in the visit felt they had learned at least '*a little*' physics (100%), and more felt they had learned '*a lot*' (14% compared to 11% for the lecture only). A smaller proportion of students said they had learned '*some*' physics (48% compared with 54%). Of course this scale is very subjective, one student's perception of '*a little*' physics may be the same as another's perception of '*a lot*'.

Students' evaluation of the visit

Overall, students who attended the visit had good impressions of the shorter version of '*Great Balls of Fire*'. Some 85% thought it interesting, and most thought the length and pace of the talk to be '*about right*' (85% and 70% respectively). Three-quarters (75%) said that the physics was pitched at the right level, and 88% liked the slides.

Most students (72%) found the tour interesting and the majority (63%) thought it was the right length, although a third (30%) of students found the tour too long. One student commented *'the tour was really tiring because the place was really huge. I suggest having a break in between'*. Most students (77%) had a positive impression of the tour guides, although a few commented that the language used was difficult. One student said *'the language the guides used was very confusing'*, but these opinions were in the minority. A few students also said that the guides had been difficult to hear.

5.3.5 Opinions of teachers

10 teachers and one learning assistant who saw the *'Great Balls of Fire'* lecture completed the teacher questionnaires. All of the teachers surveyed taught physics at AS- and A2-level. School staff had a generally positive response to the lecture, and all rated it as *'interesting'* or *'very interesting'*. Ten of the eleven respondents agreed that the length of the presentation was *'about right'*. Most respondents felt that the scientific level of the lecture was appropriate, although a minority felt it could have been either simpler or more involved:

> *"Could have been improved by the inclusion of more basic physics"*
>
> *"In principle they could have been stretched further"*

Seven of the teachers surveyed felt that the lecture had offered educational value; two of these felt that although the lecture was educational for Year 12 students, those in Year 13 would have gained little new physics knowledge. One teacher wrote

> *'some ideas were probably reinforced but not much was new to yr 13 but would have been to yr 12'.*

Teaching staff unanimously felt that lectures such as '*Great Balls of Fire*' were an effective means of communicating physics to their students. Some of their reasons for holding these opinions included the effectiveness of a different teaching method to that usually employed in the classroom, an increase in the perceived relevance of the material and the credibility of a speaker involved in real physics research. Respondents' comments included:

> *"Pupils were attentive and a different method of teaching"*
>
> *"Makes them aware of research going on at present time and that what they are learning in lessons is connected to reality"*
>
> *"If the talker is involved professionally with the topic he/she can give more relevant detail with more conviction"*

Staff felt that their students enjoyed the lecture for a number of reasons, not least its educational value. Several also commented on the lecturer's delivery technique as contributing towards making it an enjoyable experience for students:

> *"Very good presentation skills made it very interactive and enjoyable"*
>
> *"Easy to understand but not patronising"*
>
> *"They learned up-to-date physics"*

Teaching staff were asked about their aims and expectations for the lecture. Responses could be grouped largely into three categories. Teachers mentioned that the lecture should ***introduce and/or reinforce*** A2 syllabus material, ***increase interest***

and enthusiasm for the subject amongst students, and ***emphasise the relevance*** and applications of the physics involved. When asked if these expectations had been met, responses were positive, although a minority (2 teachers) would have preferred the lecture to follow the syllabus more closely. Respondents were given the opportunity to make any further comments, and several expressed their opinion of the importance of lectures such as '*Great Balls of Fire*', as well as communicating their gratitude for the lecturer's visit to their school:

> *"Excellent, more of them needed"*
>
> *"Students must see higher physics as 'exciting' if we are going to see them take physics up"*
>
> *"Thanks for coming along!"*

5.4 DISCUSSION

5.4.1 Students' attitudes, perceived ability and museum visits

Some interesting associations were observed between students' perceptions of their physics ability, how often they visited museums and science centres and their responses to the attitudinal indicators. Students who rated their ability as high and often visited museums were more likely to have a positive attitude to physics. They appeared more likely to consider physics interesting and relevant, and reject the idea that it is boring. It is not possible, however, to determine whether the link between museum and science centre visits and a positive attitude towards physics is due to the influence of the visits, or if those visits are motivated by an interest in the subject.

5.4.2 Impact of interventions

Affective impact

The results showed that the lecture had a significant impact on the students' attitudes towards physics. Students were less likely to agree that physics is an interesting subject after the lecture than beforehand, although this result could appear due to the fact that most students found physics interesting previously, as discussed in section 5.3.3. Indeed, this result would appear to contradict the evaluation responses, where the majority of students said they had found the lecture interesting. Following the lecture, more students rejected the notion that mathematical ability was important in physics, possibly due to the lecture's absence of mathematical content. Significantly fewer students rejected the idea that physics was '*more to do with remembering facts than understanding ideas*' following the lecture, which may have been a reaction to the bullet-point led presentation style used to deliver *PowerPoint*-based talks.

An interesting shift in the affective domain occurred regarding the way that the physics was communicated. Rather confusingly, more students agreed with the ideas that physics uses easy words, and that physics uses difficult words following the lecture. Fusion research does involve some complicated terminology, and the lecture used words such as '*tokamak*', '*binding energy*', '*torus*', and '*confinement*'. Perhaps this language was felt to be inaccessible to some students, but not to others. However, when the lecturer introduced new terms, an effort was made to use an analogy or simple description in order that they could be easily understood. Perhaps the introduction of complicated terminology in this way prompted the observed responses – students could have considered the words difficult and complicated while still finding them easy to understand. Further research into the language used in such interventions would clarify whether this is indeed the case. If so, it highlights the importance of the role of explanation of unfamiliar terms in the successful communication of physics.

Cognitive impact

Students performed significantly better in the test of physics knowledge after the lecture than before, indicating that '*Great Balls of Fire*' was an effective means of communicating factual knowledge. It is interesting that the most dramatic cognitive shift for the lecture sample, and the only significant shift observed in the visit sample, involved the question about temperature which challenged students' preconception that the centre of the sun is hotter than the inside of a tokamak. Borun *et al* (1993) describe how, when misconceptions are challenged in the learner, they may become more receptive to new scientific information. This may explain the strong shift in correctly answering this particular question observed in both the lecture and visit samples. Of course the method used for measuring learning in this study is primitive, as it only considers what would be described as '*surface*' knowledge (Gibbs). Fusion is, however, now covered in the A2 syllabus, which would provide an opportunity for this knowledge to become confirmed.

Comparison of interventions

Both the lecture and the visit appeared to be well received by students. However, it was not possible to collect a large data set for the visit within the timescale of this study. This made it difficult to compare the two interventions in a quantitative manner. In order to fully explore the impact of the visit on the students involved, a qualitative approach would have been more appropriate, as it would have allowed exploration of impacts on individuals rather than considering a sample statistically. It is highly unlikely that the data presented in this chapter tells the full story of the impacts of these activities. However, some interesting areas that could be included in future research have been identified, such as the effect of introducing complicated terminology. Another interesting factor is the length of time over which any impacts are sustained; as described in the introductory section, Culham staff feel that a visit is more memorable than a lecture and it would be interesting to extend the research to include a longitudinal study of impact.

Appendix 5.1

Data collection materials

- Student questionnaires, pre- and post-intervention (NB attitudinal questions and quiz questions were identical at both stages – these pages of the questionnaire are only included once)

- Teacher questionnaires

Physics Questionnaire

We are doing a big study to see what people think of some of their A level subjects, like Physics.

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics
☐	☐	☐	☐	☐

Outside school, do you ever visit Museums or Science Centres?

Lots of Times	Often	Sometimes	Very Occasionally	Never
☐	☐	☐	☐	☐

How good do you think you are at Physics?

Really Good	Quite Good	About Average	Quite Bad	Really Bad
☐	☐	☐	☐	☐

CULHAM/TALK/PRE

These questions are about Physics

Physics is an **interesting** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

You need to be **good at maths** to do physics

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more of a **boys** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is a **boring** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more to do with **remembering facts** than understanding ideas

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

The things I learn in physics **relate to my everyday life**

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

People who really like physics **don't mix very well** with other people

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more of a **girls** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **difficult, complicated** words

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is an **easy** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **easy, everyday words** but with a **different meaning**

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Quick Quiz

The following questions are about some Physics topics. Answer the questions by ticking the box that you think is the right answer.

Here is an example of how to answer the questions:

Which of the following television soaps is about life in Liverpool?

Eastenders	☐	Coronation Street	☐
Brookside	☑	Neighbours	☐

And now for the Quiz...

Which of the following is *not* a form of electromagnetic radiation

Light	☐	Gamma rays	☐
Radio wave	☐	Sound wave	☐

What is a Tritium nucleus made up from?

1 proton, 2 neutrons	☐	1 proton, 1 neutron	☐
2 protons, 2 neutrons	☐	2 protons, no neutrons	☐

Which country uses the most energy per person in the world?

Australia	☐	United Kingdom	☐
United States	☐	India	☐

Which of the following is a renewable energy source

Coal	☐	Natural Gas	☐
Solar Power	☐	Oil	☐

Which of the following is ***not*** an advantage of fusion power?

No greenhouse emissions	☐	Tokamaks are easy to build	☐
No Long-lived radioactive waste	☐	Plentiful fuel supply	☐

Where is Deuterium extracted from?

Water	☐	Crude Oil	☐
Salt	☐	Sandstone	☐

Which of the following has reached the highest temperature?

A Boiling Kettle	☐	The centre of the Sun	☐
The JET plasma	☐	A light bulb filament	☐

Which of the following is an everyday example of a plasma

Magnetised Steel	☐	Concrete	☐
Steam	☐	Lightning	☐

What is the name of the main set of fusion reactions that occur in the Sun?

The proton-proton chain	☐	The Craymore reactions	☐
The nucleon cycle	☐	The P-Type phase	☐

Which law of Physics halts the collapse of a large dying star?

Heisenberg Uncertainty principle	☐	Pauli Exclusion Principle	☐
Kirchoff's Second Rule	☐	Newton's Laws of motion	☐

Thanks!

School Talk Questionnaire

We are doing a big study to see what people think of some of their A level subjects, like Physics. We would also like to know your opinions on the presentation "Great Balls of Fire".

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

☐	☐	☐	☐	☐
I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics

CULHAM/TALK/POST

These Questions are about the Presentation "Great Balls of Fire"

Did you see the "Great Balls of Fire" presentation?

☐ Yes ☐ No

What did you think of the presentation?

☐	☐	☐	☐	☐
Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring

What did you think of the length of the presentation?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

What did you think of the pace (speed) of the presentation?

☐	☐	☐	☐	☐
Much Too Fast	Too Fast	About Right	Too Slow	Much Too Slow

What did you think about the Physics in the presentation?

☐	☐	☐	☐	☐
Much Too Easy	Too Easy	About Right	Too Difficult	Much Too Difficult

What did you think of the presentation slides?

☐	☐	☐	☐	☐
Very Good	Good	Neither Good Nor Bad	Bad	Very Bad

How much Physics do you think you learned from the presentation?

☐	☐	☐	☐
A Lot	Some	A Little	None

What do you think the aim of the presentation was?

Do you think that the aim has been fulfilled?

☐ Yes ☐ No ☐ Don't Know

Do you think that the presentation has changed the way you feel about Physics?

☐ Yes ☐ No ☐ Don't Know

If YES, in what way?

If you have any other comments about the presentation, please write them in the box below:

Thanks!

Physics Questionnaire

We are doing a big study to see what people think of some of their school subjects, like Physics.

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

☐	☐	☐	☐	☐
I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics

Outside school, do you ever visit Museums or Science Centres?

☐	☐	☐	☐	☐
Lots of Times	Often	Sometimes	Very Occasionally	Never

How good do you think you are at Physics?

☐	☐	☐	☐	☐
Really Good	Quite Good	About Average	Quite Bad	Really Bad

CULHAM/VISIT/PRE

These questions are about Physics

Physics is an **interesting** subject

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

You need to be **good at maths** to do physics

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

Physics is more of a **boys** subject

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

Physics is a **boring** subject

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

Physics is more to do with **remembering facts** than understanding ideas

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

The things I learn in physics **relate to my everyday life**

I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree
☐	☐	☐	☐	☐

People who really like physics **don't mix very well** with other people

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is more of a **girls** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **difficult, complicated** words

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics is an **easy** subject

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Physics uses **easy, everyday words** but with a **different meaning**

☐	☐	☐	☐	☐
I strongly agree	I agree	I neither agree nor disagree	I disagree	I strongly disagree

Quick Quiz

The following questions are about some Physics topics. Answer the questions by ticking the box that you think is the right answer.

Here is an example of how to answer the questions:

Which of the following television soaps is about life in Liverpool?

Eastenders	☐	Coronation Street	☐
Brookside	☑	Neighbours	☐

And now for the Quiz...

Which of the following is *not* a form of electromagnetic radiation

Light	☐	Gamma rays	☐
Radio wave	☐	Sound wave	☐

What is a Tritium nucleus made up from?

1 proton, 2 neutrons	☐	1 proton, 1 neutron	☐
2 protons, 2 neutrons	☐	2 protons, no neutrons	☐

Which country uses the most energy per person in the world?

Australia	☐	United Kingdom	☐
United States	☐	India	☐

Which of the following is a renewable energy source

Coal	☐	Natural Gas	☐
Solar Power	☐	Oil	☐

Which of the following is ***not*** an advantage of fusion power?

No greenhouse emissions	☐	Tokamaks are easy to build	☐
No Long-lived radioactive waste	☐	Plentiful fuel supply	☐

Where is Deuterium extracted from?

Water	☐	Crude Oil	☐
Salt	☐	Sandstone	☐

Which of the following has reached the highest temperature?

A Boiling Kettle	☐	The centre of the Sun	☐
The JET plasma	☐	A light bulb filament	☐

Which of the following is an everyday example of a plasma

Magnetised Steel	☐	Concrete	☐
Steam	☐	Lightning	☐

What is the name of the main set of fusion reactions that occur in the Sun?

The proton-proton chain	☐	The Craymore reactions	☐
The nucleon cycle	☐	The P-Type phase	☐

Which law of Physics halts the collapse of a large dying star?

Heisenberg Uncertainty principle	☐	Pauli Exclusion Principle	☐
Kirchoff's Second Law	☐	Newton's Laws of motion	☐

Thanks!

School Visit Questionnaire

We are doing a big study to see what people think of some of their school subjects, like Physics. We would also like to know your opinions on the trip to Culham Science Centre.

Please take a few moments to answer the following questions

Firstly, some information about yourself...

Your First Name.............................. Your Surname...............................

Age .... School Year group ....

Male/Female .... School ....

How do you feel about Physics?

☐	☐	☐	☐	☐
I really like Physics	I quite like Physics	I neither like nor dislike Physics	I don't like Physics much	I really don't like Physics

CULHAM/VISIT/POST

These Questions are about the Presentation "Great Balls of Fire"

Did you see the "Great Balls of Fire" presentation?

☐ Yes ☐ No

What did you think of the presentation?

☐	☐	☐	☐	☐
Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring

What did you think of the length of the presentation?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

What did you think of the pace (speed) of the presentation?

☐	☐	☐	☐	☐
Much Too Fast	Too Fast	About Right	Too Slow	Much Too Slow

What did you think about the Physics in the presentation?

☐	☐	☐	☐	☐
Much Too Easy	Too Easy	About Right	Too Difficult	Much Too Difficult

What did you think of the presentation slides?

☐	☐	☐	☐	☐
Very Good	Good	Neither Good Nor Bad	Bad	Very Bad

How much Physics do you think you learned from the presentation?

☐	☐	☐	☐
A Lot	Some	A Little	None

If you have any other comments about the presentation, please write them in the box below:

These Questions are about the Tour

Which part/s of the Science Centre did you visit?

☐	☐	☐	☐
JET	MAST	JET & MAST	Other...........................

What did you think about the tour?

☐	☐	☐	☐	☐
Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring

What did you think about the length of the tour?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

What did you think about the way the guide explained the experiments?

☐	☐	☐	☐	☐
Very Good	Good	Neither Good Nor Bad	Bad	Very Bad

Did you think that the tour was a fun way to learn some Science?

☐	☐	☐	☐	☐
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

How much Science do you think you learned from the tour?

☐	☐	☐	☐
A Lot	Some	A Little	None

If you have any other comments about the tour, please write them below:

These Questions are about the Day as a Whole

What do you think the aim of the day was?

Do you think that the aim has been fulfilled?

☐ Yes ☐ No ☐ Don't Know

Do you think that the event has changed the way you feel about Physics?

☐ Yes ☐ No ☐ Don't Know

If YES, in what way?

Please tell us how you think we could improve the day. Please write as much as you can:

Thanks!

Teacher Questionnaire

We are interested in your thoughts about the **Great Balls of Fire** presentation.

Please take a few moments to complete this questionnaire - your comments will help us tailor future events to your needs.

Firstly, some information about yourself...

School ....

Which subject do you teach?...

Student Year group involved in presentation...

Male/Female ....

These questions are about the Presentation

Did you see the "Great Balls of Fire" presentation?

☐ Yes ☐ No

What did you think of the presentation?

☐	☐	☐	☐	☐
Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring

What did you think of the length of the presentation?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

Do you think that the presentation was at the right level for your students? If not, in what way?

Do you think that your students learned much Physics from the presentation?

Do you think that a presentation such as this is an effective means of communicating Physics to your students? Why?

Do you think that the talk was enjoyable for your students? Why?

What were your aims and expectations for the talk?

Have your aims been fulfilled? Why?

If you have any other comments about the presentation, please write them below.

Thanks!

CULHAM/TALK/TEACHER

Teacher Questionnaire

We are interested in your thoughts about your recent visit to Culham Science Centre.

Please take a few moments to complete this questionnaire - your comments will help us tailor future events to your needs.

Firstly, some information about yourself...

School ....

Which subject do you teach?...

Student Year group involved in visit...

Male/Female ....

CULHAM/VISIT/TEACHER

These questions are about the presentation "Great Balls of Fire"

Did you see the "Great Balls of Fire" presentation?

☐ Yes ☐ No

What did you think of the presentation?

☐	☐	☐	☐	☐
Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring

What did you think of the length of the presentation?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

Do you think that the presentation was at the right level for your students?

Do you think that your students learned much Physics from the presentation?

Do you think that a presentation such as this is an effective means of communicating Physics to your students? Why?

If you have any other comments about the presentation, please write them here:

These Questions are about the Tour

Which part/s of the Science Centre did you visit?

☐	☐	☐	☐
JET	MAST	JET & MAST	Other...........................

What did you think about the tour?

☐	☐	☐	☐	☐
Very Interesting	Interesting	Neither Interesting nor Boring	Boring	Very Boring

What did you think about the length of the tour?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

What did you think about the way the guide explained the experiments?

If you have any other comments about the tour, please write them here:

These Questions are about the Day as a Whole

Do you think that the day was useful and enjoyable for your students? Why?

What were your aims and expectations for the visit?

Have your aims been fulfilled? Why?

Please tell us how you think we could improve the event. Please write as much as you can:

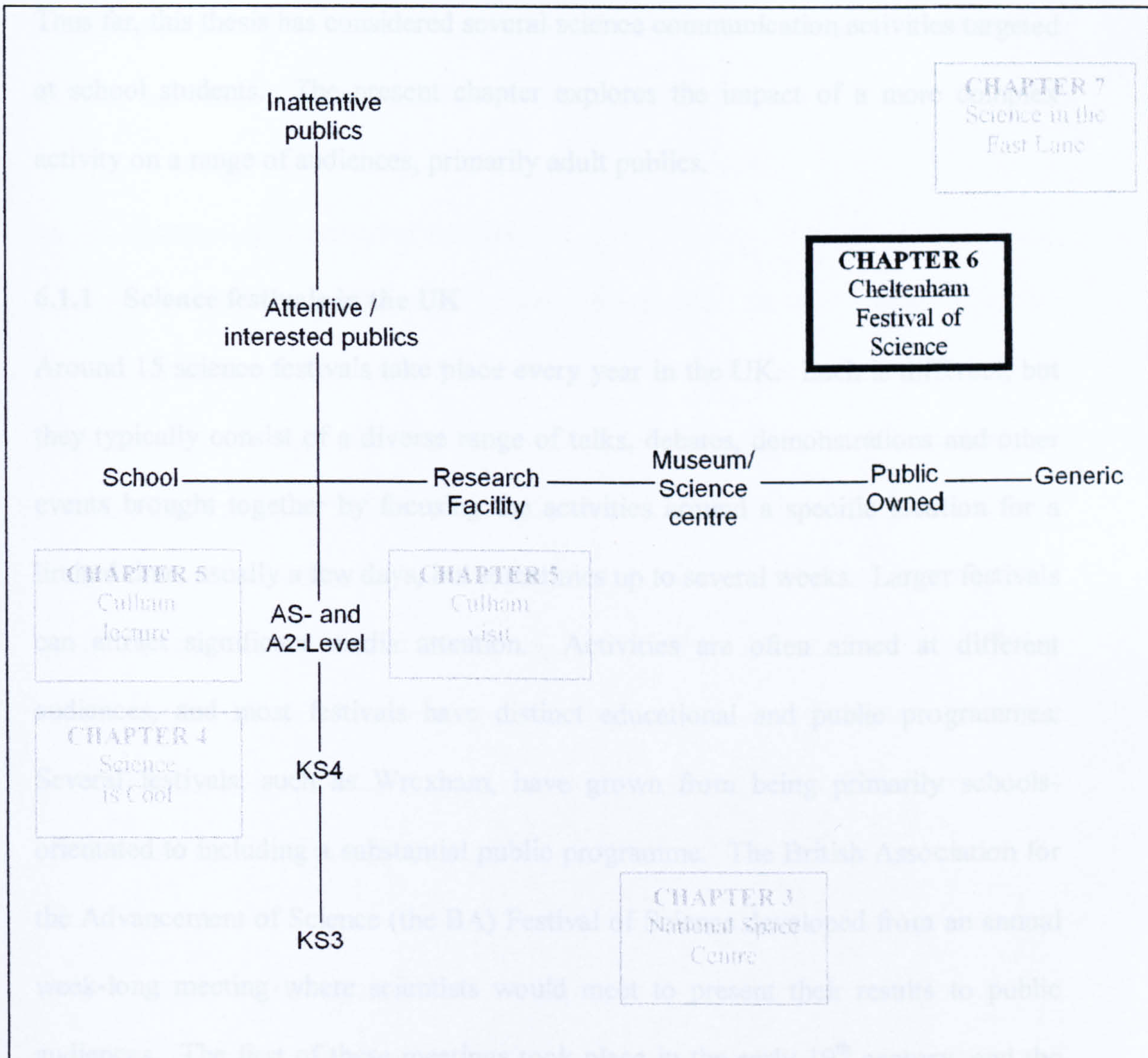
Do you have any ideas for other events which you would like to see organised at Culham Science Centre? Please write them below:

Thanks!

Chapter 6

EVALUATION OF THE IMPACT OF A SCIENCE FESTIVAL ON ITS VISITORS

Research axes



Horizontal axis shows activity venue, vertical axis shows activity target audience

Chapter 6 explores the impact of a science festival on its visitors, with the focus on adult audiences. Questionnaires, interviews and electronic voting were used to gather the opinions of festivalgoers. A postal survey was also conducted six months after the festival to explore longer-term impacts. Festival visitors were typically 'attentive' or 'interested' publics. It appeared that the impact of individual events within the festival were mostly cognitive, while the impact of the festival as a whole was cognitive and affective. Some behavioural changes were also reported in the follow-up sample.

6.1 INTRODUCTION

Thus far, this thesis has considered several science communication activities targeted at school students. The present chapter explores the impact of a more complex activity on a range of audiences, primarily adult publics.

6.1.1 Science festivals in the UK

Around 15 science festivals take place every year in the UK. Each is different, but they typically consist of a diverse range of talks, debates, demonstrations and other events brought together by focusing the activities around a specific location for a limited time, usually a few days, but sometimes up to several weeks. Larger festivals can attract significant media attention. Activities are often aimed at different audiences, and most festivals have distinct educational and public programmes. Several festivals, such as Wrexham, have grown from being primarily schools-orientated to including a substantial public programme. The British Association for the Advancement of Science (the BA) Festival of Science developed from an annual week-long meeting where scientists would meet to present their results to public audiences. The first of these meetings took place in the early 19th century, and the BA Festival of Science is now held in a different city each year. The Edinburgh International Festival of Science claims to be the world's first Science Festival; it started in 1989 and has run every year since. The Oxfordshire science festival has existed for a similar period of time.

The present study focused on a single festival, the 2003 Cheltenham Festival of Science. The study was designed to assess the festival in terms of the extent to which it achieved its aims, according to opinions of the festivalgoers. Another aspect of the research was to ascertain the impact of both the festival as a whole, and the individual events within it, on the cognitive, affective and behavioural domains of its visitors. Festivalgoer demographics were also considered.

6.1.2 Cheltenham Festival of Science

A number of festivals take place in Cheltenham each year, the most famous being the two annual literature festivals. For this reason, the town has a dedicated festival office whose staff oversee the organisation and delivery of all Cheltenham festivals. Cheltenham Festival of Science was conceived in 2001, and the first festival took place in June 2002. The festival was regarded as a success by the organisers and those who attended; the second festival took place in June 2003, and the third in June 2004. A key element of the festival is the stress it places on dialogue, namely the interaction between scientists and publics, described in more detail in Section 1.4.2 of the introductory chapter of this thesis.

6.1.3 Festival description

The 2003 Cheltenham Festival of Science took place from 4th to 8th June 2003, and consisted of a number of events taking place in various venues around Cheltenham. The festival was centred on the Town Hall, the primary venue, and the Everyman Theatre, the secondary venue. The idea behind limiting the number of venues was to maintain a focus for the festival, and maximise its impact. The *Discover Zone* was the interactive area of the festival, and entry was free. It was housed in the main hall at the primary venue, and provided noise and activity with disco lighting, sound effects and dry ice. The *Work Shop* was situated at one end of the *Discover Zone*, and consisted of a number of drop-in events. The *Space and Time Tent* was a new addition to the Festival for 2003, and housed the robot arena and a number of stalls, as well as a café area designed to act as an area where visitors could relax. The *Science Cafés* were dialogue events where three specialists would discuss a particular issue with members of the audience, and were held in the tent. The *talks* and *debates* which made up most of the programme of events, were aimed at adult audiences, and took place in the Town Hall (Pillar Room and Drawing Room) or the Everyman Theatre. *Talks* consisted of a presentation given by the speaker, and *debates* often involved a panel of speakers followed by a discussion where audience members were encouraged to participate. The festival also had a schools and family programme; while these events are considered in the present study, the main focus was on the impact of the festival on its adult audiences.

6.1.4 Festival aims

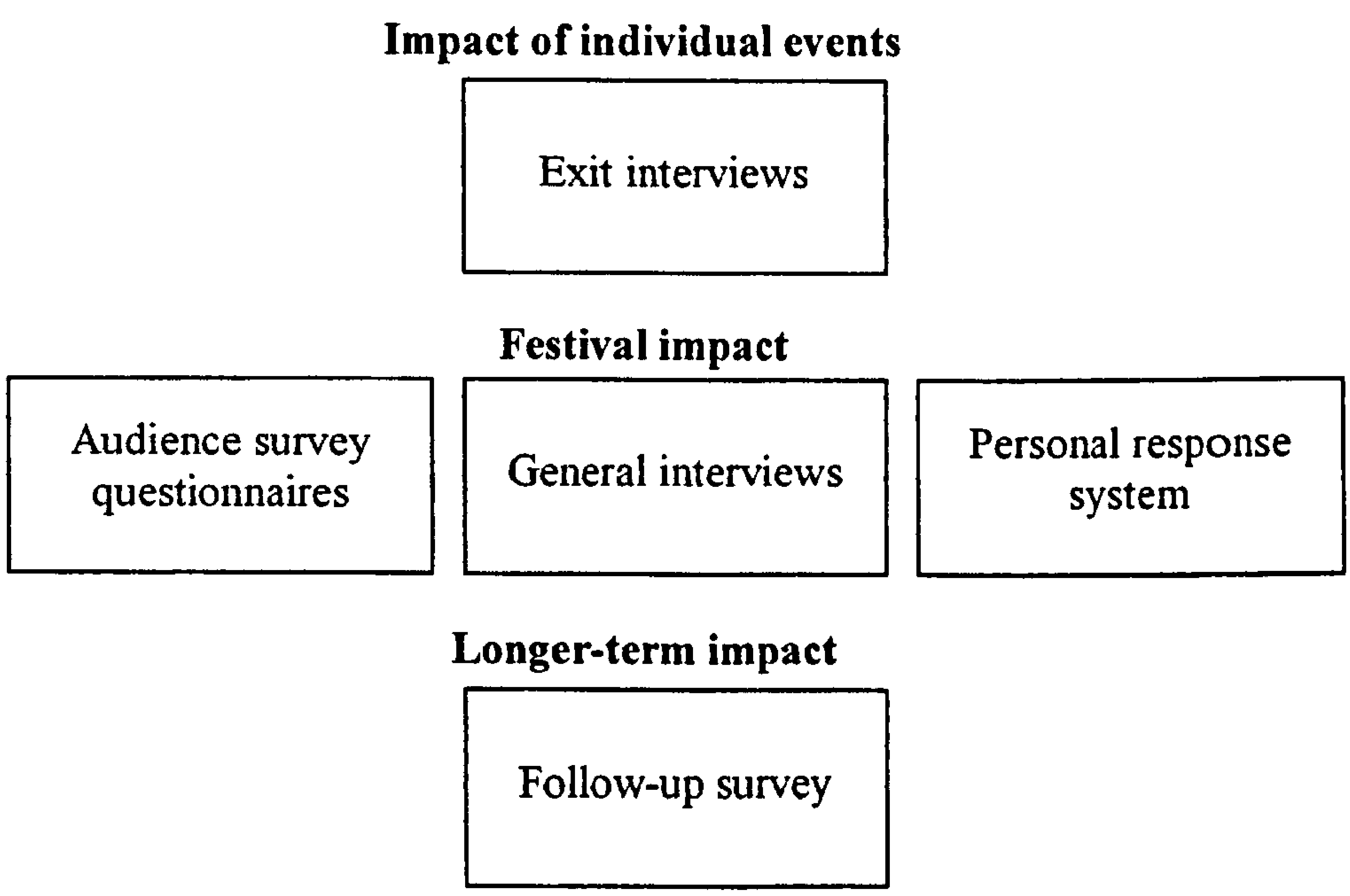
In 2003, the festival aimed to present scientific ideas and issues in a festive, enjoyable environment, and to create opportunities for the public to gain confidence in and have access to science and the debates around it. Using different ways of encouraging participation in discussion of scientific issues from those who had not necessarily taken part in such discussions before was also an objective of the festival. The festival aimed to target different audiences separately; with each group finding some of the activities accessible. The directors and organisers intended the festival to be perceived as high quality and focused, and hoped to establish its national and international profile.

6.2 METHODOLOGY

6.2.1 Data collection

Data were collected in a number of ways. Firstly, the festival organisers collected metric data including ticket sales and attendance figures. Secondly, questionnaire-based interviews with festivalgoers were conducted. Thirdly, data from the audience survey questionnaires used by the festival organisers for the evaluation of all Cheltenham festivals were made available for the research. Fourthly, a personal response system (PRS) allowed data to be collected electronically from visitors to a number of events. Fifthly, a feedback session was held on the final day of the festival that brought together festival directors, organisers and visitors. In addition to this, a follow-up survey of festivalgoers was conducted 6 months after the festival. The ways in which the different methods were used is indicated in Figure 6.1.

Figure 6.1 Data collection methods



Exit and general interviews

Interviews were conducted as audience members left specific events, and at random during the festival. The structured interview comprised two parts, a *general* and a *specific* part. All interviewees were asked the *general* questions, about their demographic details, opinions of the festival (these questions were designed on the basis of the festival aims), and whether the interviewee would be prepared to take part in the follow-up stage of the evaluation. The *specific* questions related to particular events, and were only included in the exit interviews. A copy of the interview questionnaire is given in Appendix 6.1.

Some questions relating to the dialogue process were also included, such as whether people felt comfortable contributing to the sessions. Interviewing was selected as a methodology in this case for two reasons: firstly because the sample would not be self selecting; and secondly because the festival organisers were particularly interested in the opinions of 18-25 year-olds, and conducting interviews allowed this group to be targeted to some extent. The interviews were carried out by an evaluation team consisting of the researcher and two volunteers who had been trained in appropriate interviewing technique. Interviews were conducted in both of the main festival venues, the Town Hall and the Everyman Theatre. In order to collect data regarding a particular event, the evaluation team conducted exit interviews following specific events. General interviews were also conducted throughout the festival.

Audience survey questionnaires

The audience survey questionnaires were available from festival information points, for festivalgoers to leave feedback at any time, and were also left on seats at some events to encourage their completion. The surveys went into more detail about the demographics of festivalgoers, with questions that probed their level of education, media usage and leisure interests. The main problem with this data collection method was the self-selecting nature and resultant bias of the sample. A copy of the audience survey questionnaire is given in Appendix 6.1, with the other data collection instruments.

Personal response system

A personal response system was available for use in some of the festival events, and this was also used to collect evaluation data electronically. The system allows individuals to register their responses by pressing a button on a keypad, which transmits the data to a central receiver using radio waves. The advantage of this system was that it was easy to collect responses from a large number of festivalgoers, and that respondents can be assured that their responses are completely anonymous. The disadvantage was that due to time constraints only a limited number of questions were used and all questions had to be closed form. Nevertheless a large amount of data relating to audience demographics and impressions of the festival were collected.

Follow-up survey

During the structured interviews, interviewees were, where possible, recruited into the follow-up stage of the evaluation. A postal questionnaire survey of festivalgoers was conducted using questions similar to those used in the interviews in order that a comparison could be made. The questionnaires were also designed to examine the impact of the festival on the cognitive, affective and behavioural domains of visitors.

6.3 RESULTS

6.3.1 Attendance and ticket sales

The total number of tickets sold for events was 13,062, an increase of around 1,400 on 2002 sales. When the number of visitors to the free *Discover Zone* was included, the total number of visitors was estimated to have exceeded 20,000. From the interview sample, 62% said they had booked tickets in advance, with the remainder having attended spontaneously.

6.3.2 The study cohort

Figure 6.2 shows the numbers of festivalgoers in each of the samples in the research.

Figure 6.2 *Samples involved in the survey*

Sample	*n*	*Male %*	*Female %*	*Under 18 %*	*18-24 %*	*25-34 %*	*35-44 %*	*45-54 %*	*55-64 %*	*65+ %*
Total	725	49	51	5	6	17	20	19	16	17
Exit interviews	36	39	61	14	11	22	14	14	17	8
General interviews	186	48	52	13	8	22	26	16	7	8
Audience survey	193	48	52	3	3	15	20	21	18	19
Personal response system (PRS)	346	51	49	2	6	16	17	19	19	21
Follow-up	43	44	56	2	5	16	2	21	9	14

Sample sizes do not total 725 because some respondents were included in more than one sample. Percentages may not total 100 due to rounding

Sample demographics

Over half of the festivalgoers surveyed (in all samples) were over the age of 45, with a large proportion over the age of 65. The most under-represented age groups in the audience survey and PRS samples were the under 18s and the 18-24s. The under 18 group was better represented in the interview sample because this sample included people attending the schools events. It is worth highlighting, however, that the 18-24 age bracket is the narrowest, so this group is likely to be smaller for that reason. The interview, audience survey, PRS and follow-up surveys had a roughly equal numbers of males and females. The exit interview sample was predominantly female. There was an excellent response to the postal follow-up survey, over 70% of questionnaires were returned. This suggests that the members of this sample had a high level of engagement in the festival, providing motivation to complete the survey.

Both the audience survey and interview samples showed that at least half of respondents were from the ABC1 demographic group, comprising professionals and non-manual workers (52% audience survey respondents and 50% interviewees). A high proportion of festivalgoers were retired (27% audience survey respondents and 9% interviewees). The interview sample contained a smaller proportion of professionals/senior managers and retired people, probably due to the more balanced spread cross the age groups. This is also likely to explain the larger proportion of students in this sample (21% for interviews compared to 7% for audience surveys). In both samples, the proportion of skilled manual workers, homemakers and unemployed people was small or non-existent (audience surveys: 8%, 4% and 0% respectively; interviews: 5%, 5% and 1% respectively).

Information on the media usage of festivalgoers was collected for the audience survey sample. Results showed that 86% of audience survey respondents regularly read daily 'broadsheet' newspapers, compared to a national average of just 19% (National Statistics, 2003). The same proportion of festivalgoers read 'broadsheet' newspapers on a Sunday. The most popular radio station among audience survey respondents was Radio 4, with over half (54%) of respondents listening regularly. Classic FM and Radio 3 were also popular. Audience survey respondents were most likely to visit museums/exhibitions, talks/lectures, the cinema and the theatre. It is important to remember, however, that the audience survey sample was self-selecting, so these demographics may not be typical of festivalgoers in general.

Additional demographic information was obtained from the audience survey sample and is summarised here: some 85% of audience survey respondents had a degree, and 50% had a postgraduate qualification. This compares to national figures of just 8% and 3% respectively, and a regional figure of 14% for any higher qualifications, (National Statistics, 2003; Cheltenham Festivals). It is clear from this that festivalgoers in the audience survey sample had, on the whole, a level of education far higher than the national and regional averages. This was, however, a self-selecting sample, so these demographics may not be typical of festivalgoers in general.

Attitude towards science, science media usage and science leisure activities

Pre-existing attitudes towards science were probed during the interviews. Four out of five interviewees (82%) had a pre-existing positive attitude towards science, saying they either '*liked*' or *'really liked'* science, with 57% of the sample stating the latter. Some 16% of interviewees neither liked nor disliked science, and three respondents (2%) said they didn't like science much. No interviewee claimed to *'really dislike science'*. Most festivalgoers included in the PRS and interview samples (83% PRS, 94% interview) visited science events or attractions at least once annually, and 89% of both samples used science media (read about science, watched/listened to science programmes on TV or radio) at least once per month.

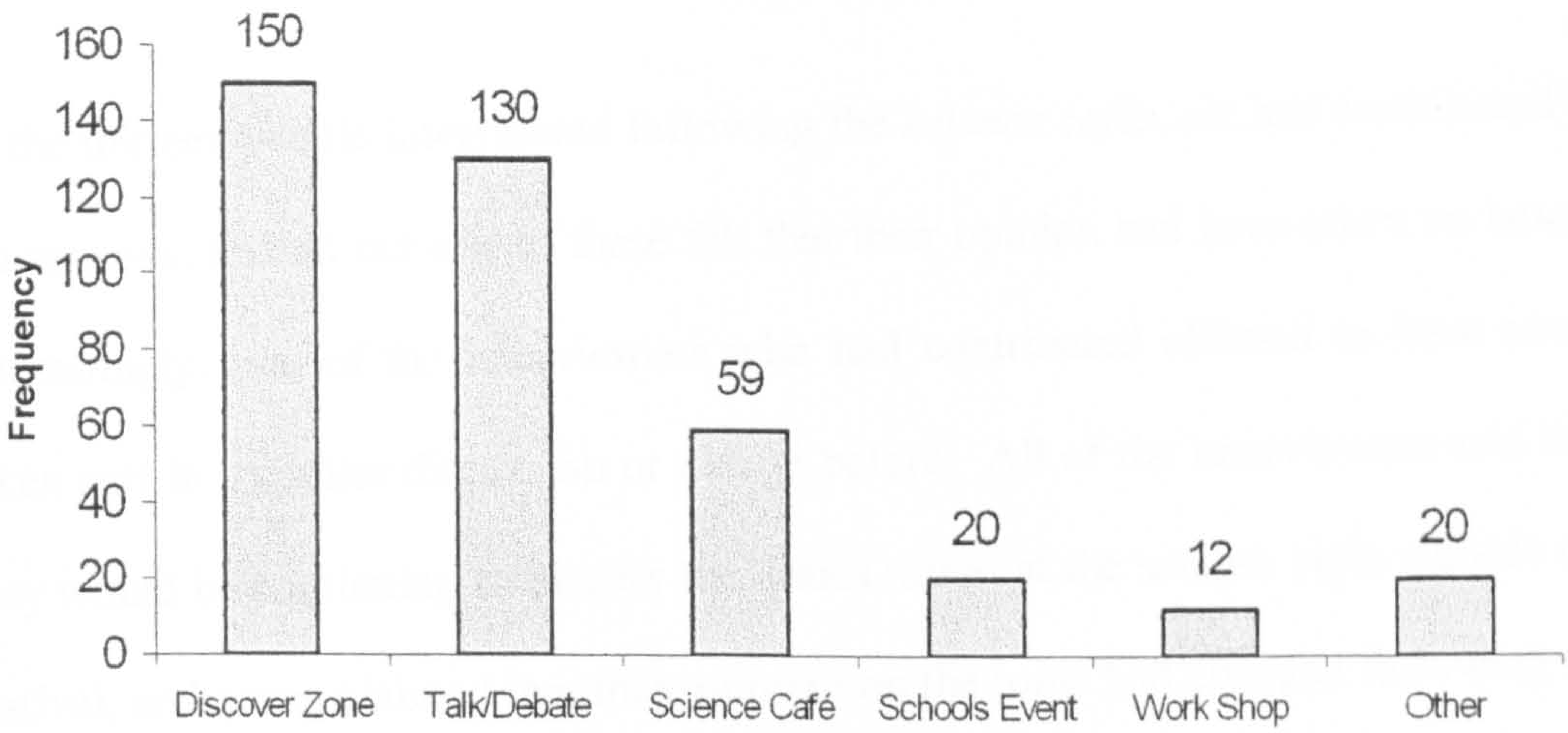
6.3.3 The nature of a festival visit

In both the interview and audience survey samples, a large proportion of festivalgoers attended for more than one day (75% in audience surveys and 65% from interviews), with around a quarter (27% in audience surveys and 25% from interviews) attending for four days or more. Interestingly, the interview sample contains more respondents who attended the festival for only one day (35%, compared to 25%). This might be due to the self-selecting nature of the audience survey sample, whose members may have a greater interest in the Cheltenham festivals (more of them are on the mailing list), so are likely to spend a greater amount of time at the festival.

Interviewees were asked for the first part of their postcode in order to judge the distance they had travelled to attend the festival. Over half of the respondents (60%) were from Cheltenham and the surrounding area, with 83% travelling from the Cheltenham postcode area or an adjacent postcode area.

Figure 6.3 shows how many visitors each part of the festival received from the interview sample.

Figure 6.3 *Parts of the festival visited by members of the interview sample*



The *Discover Zone* was the most visited part of the festival, closely followed by the *talks* and *debates*. It became apparent in several of the interviews that students who had attended *schools events* during the week had returned at the weekend to visit the *Discover Zone.*

6.3.4 Impact of individual events

In order to compare the impacts of the individual events within the festival with impressions of the festival as a whole, exit interviews were conducted following specific events. In total, 34 exit interviews were conducted following *talks, debates* and *science cafés*. Interviewees were asked if they felt that attending the individual event had changed their opinion on the topic, and were then probed as to the nature of the change. Comments collected in this way largely indicate a shift in the cognitive domains of audience members. A number of comments related to the specific content of the session, or described gaining information or learning:

> *"Clarity of understanding"* (25-34 year-old female)
>
> *"Importance of nutrition"* (55-64 year-old male)

"More information validated and confirmed"
(45-54 year-old female)

Of the thirteen people interviewed following the *science cafés*, six had contributed to the sessions, and all but one of these felt that their opinion had been taken on board. Interestingly, two of the interviewees who had contributed claimed to have never taken part in a similar discussion or debate before. All of the interviewees said that they would be continuing to discuss the issues raised at the *science cafés* outside the festival, and seven claimed that their opinion on the topic had changed following the session. Comments from interviewees following the *science cafés* indicated that they were less sure of the nature of any change in opinion than those interviewed following the *talks.*

"Lets me see opposing views" (55-64 year-old female)

"[I am] *confused – I didn't disagree with anyone!"*
(45-54 year-old female)

"It was more starting a discussion than learning"
(25-34 year-old female)

There was also evidence that one of the *debates* may have induced a behavioural change in its audience members. The '*Recycling is Rubbish'* event involved a panel of three speakers who each gave a short presentation, followed by a question-and-answer session where the topic generated a significant amount of discussion. The personal response system was used at the end of the session, with questions that related to the audience's pre-existing recycling habits and whether they had been prompted to change those habits following the debate. The results showed that most of the audience already recycled paper (96%) and that they would continue or start to do so (99%). The same was true for glass (87% and 88% respectively). The interesting result concerned the recycling of plastic, which had been discussed during the session. Only 28% of the audience recycled plastic before the event, but 48% claimed that they would continue or start to do so by the end. It is not certain whether all these claims would result in a change in behaviour; however, the data do indicate a change in the audience's intentions.

6.3.5 Opinions of the festival

Visitors were asked to rate the festival in two ways, quantitatively and qualitatively. The personal response system (PRS) sample were only able to respond quantitatively, interviewees were asked to rate the festival quantitatively and qualitatively, and audience survey respondents were asked to complete a quantitative rating, but had the option of leaving additional comments in an open-form questionnaire item.

Quantitative Rating

In all three samples respondents were asked to rate the festival on a scale from very good to very bad, or excellent to very poor. Figures 6.4 and 6.5 show the frequency of responses for the three samples.

Figure 6.4 *Festival rating for interview and PRS samples*

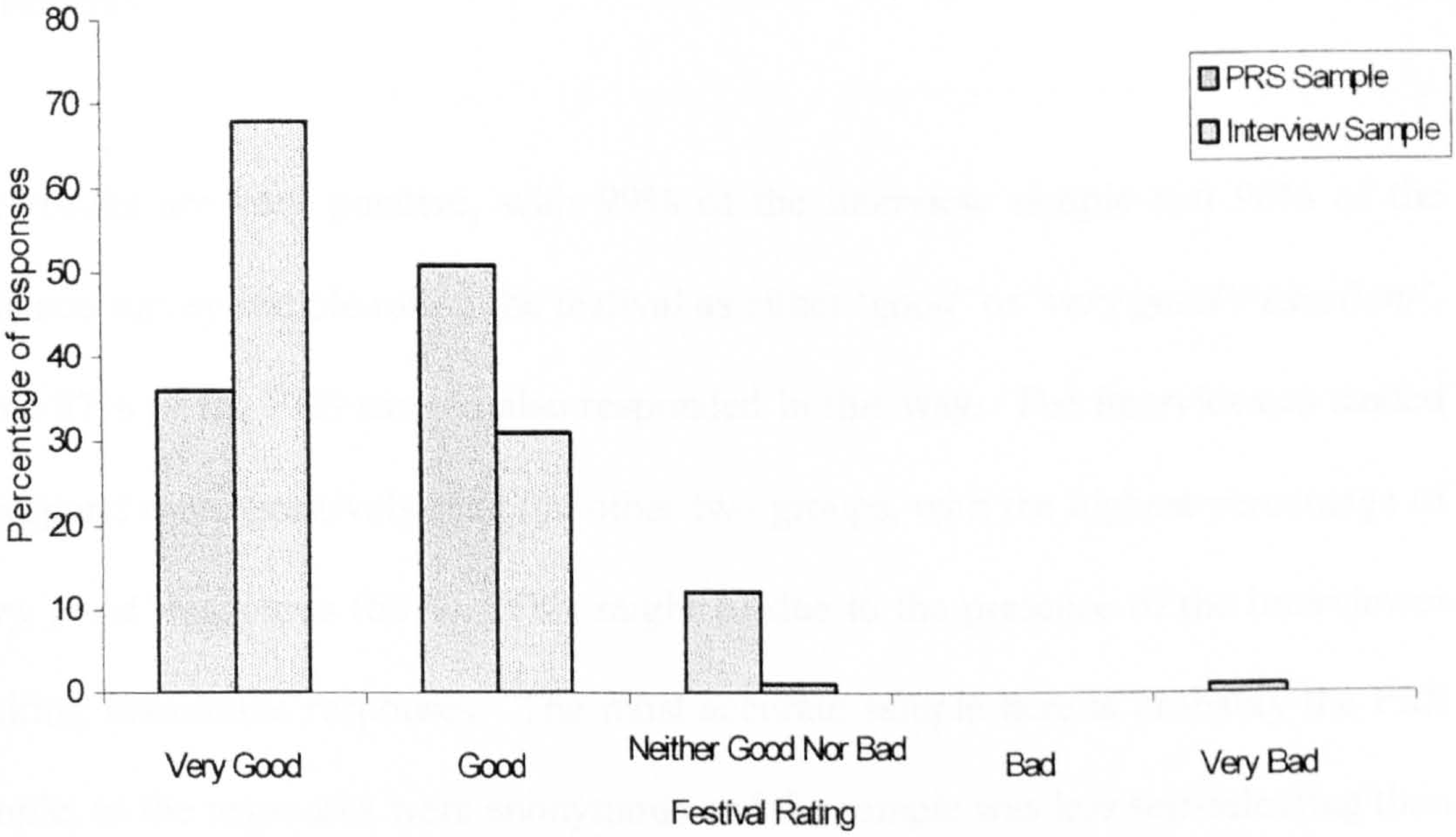
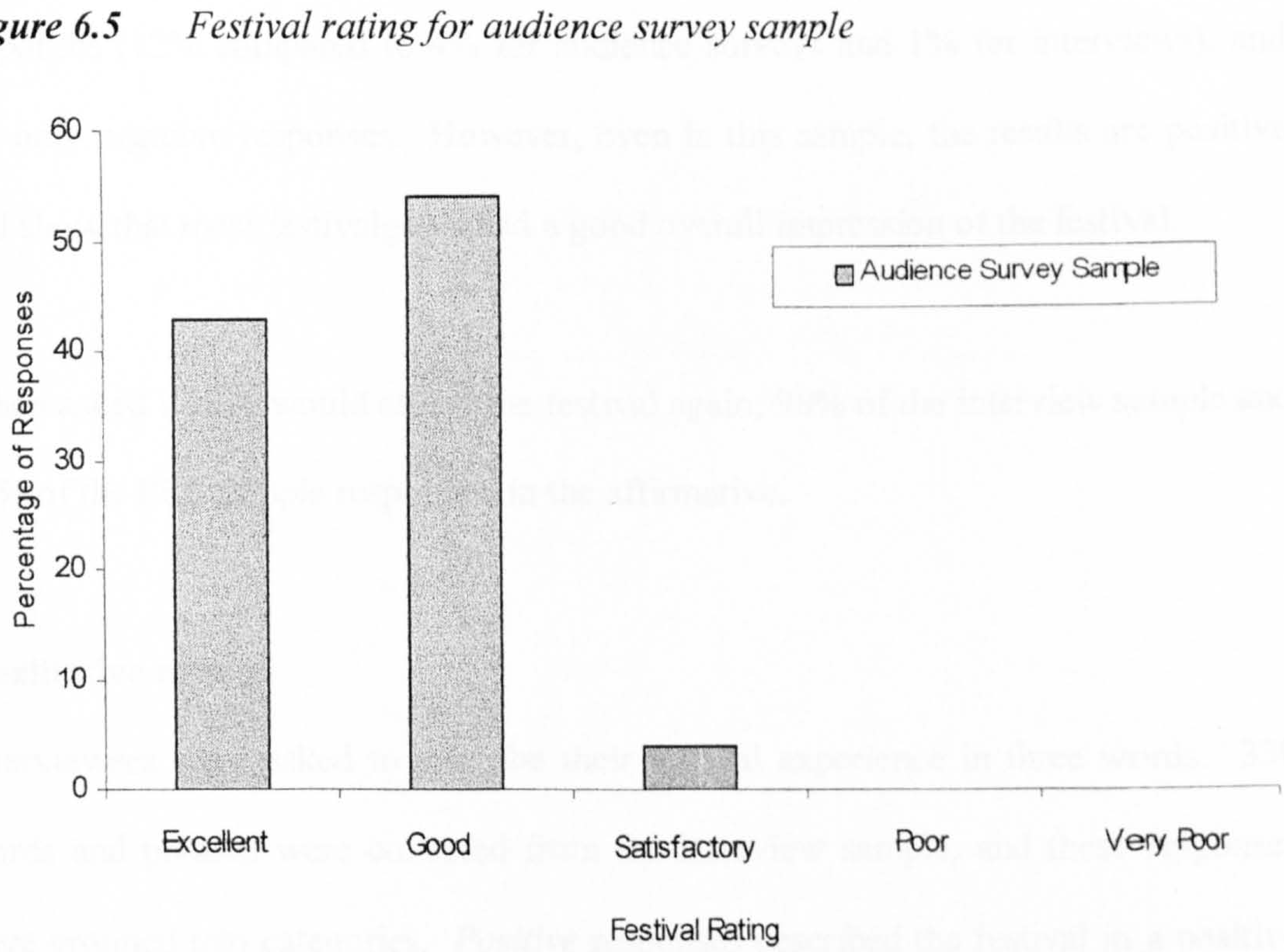


Figure 6.5 *Festival rating for audience survey sample*



The category scales on the graphs differ because of the ways in which the data were used. It was necessary to maintain continuity between the scales used in this chapter and other chapters of this thesis; however the audience survey data were also used by

Cheltenham festivals, who needed to maintain continuity with other data collection instruments.

The results are very positive, with 99% of the interview sample and 96% of the audience survey sample rating the festival as either *'good'* or *'very good'/'excellent'*. Some 87% of the PRS sample also responded in this way. The interviewees tended to respond more positively than the other two groups, with the highest percentage of *'very good'* responses (68%). This might be due to the presence of the interviewer eliciting favourable responses. The most accurate sample here is probably the PRS sample, as the responses were anonymous and the sample was less self-selecting than the audience survey sample. This is reflected in the larger proportion of neutral responses (12% compared to 4% for audience surveys and 1% for interviews), and the only negative responses. However, even in this sample, the results are positive and show that most festivalgoers had a good overall impression of the festival.

When asked if they would attend the festival again, 98% of the interview sample and 97% of the PRS sample responded in the affirmative.

Qualitative rating

Interviewees were asked to describe their festival experience in three words. 330 words and phrases were collected from the interview sample, and these responses were grouped into categories. ***Positive*** responses described the festival in a positive manner, and ***superlative*** responses expressed extremely positive sentiments. A few respondents expressed ***negative*** sentiments. Many festivalgoers described the festival as ***fun*** or enjoyable, and some responses reflected the festival's perceived

educational value. Some comments highlighted the level of ***interaction*** or engagement at the festival, and some indicated that the perceived primary target audience for festival events was ***children***. Many respondents described the festival as ***interesting*** or ***stimulating***, these two sentiments have been separated for the purpose of this analysis. Comments were made on the festival ***atmosphere***, or described the festival in terms of its ***diversity***. Finally, some respondents remarked on the festival's professional ***organisation***.

The numbers of words in each category were recorded, and Figure 6.6 summarises the results of this analysis. Some phrases were coded twice, e.g. '*great for kids*' fits into both the superlative and the children categories. For a comprehensive list of all the words and phrases included in each of the categories, please refer to Appendix 6.2.

Figure 6.6 *Results of category analysis for qualitative festival rating*

Category	*Number of Responses*
Fun	65
Interesting	55
Educational	49
Superlative	45
Positive	40
Stimulating	28
Atmosphere	17
Negative	11
Diversity	8
Interaction	4
Organisation	4
Children	4

The most common responses were in the ***fun***, ***interesting*** and ***educational*** categories.

Popularity of festival events

These data were gathered from the interview sample, who were asked which had been their favourite and least favourite festival events. Respondents stated that the talks and debates were their favourite part of the festival most frequently. Reasons for this included:

> *"Because it was aimed at adults"* (25-34 year-old male)
>
> *"[the Quantum event] was a simple insight into a complex concept"* (35-44 year-old female)
>
> *"Hearing famous intellectuals speak"* (55-64 year-old female)

The *Discover Zone* was also popular. Reasons for this included:

> *"They let you do it – it's more fun"* (10-year-old female)
>
> *"You can walk up, learn something and walk away"* (35-44 year-old male)
>
> *"Good fun, free and interactive"* (25-34 year-old male)

Many respondents felt there was no part of the festival that they had not enjoyed. This in itself is a positive result. A few events were singled out as being disappointing; reasons included late cancellation of activities.

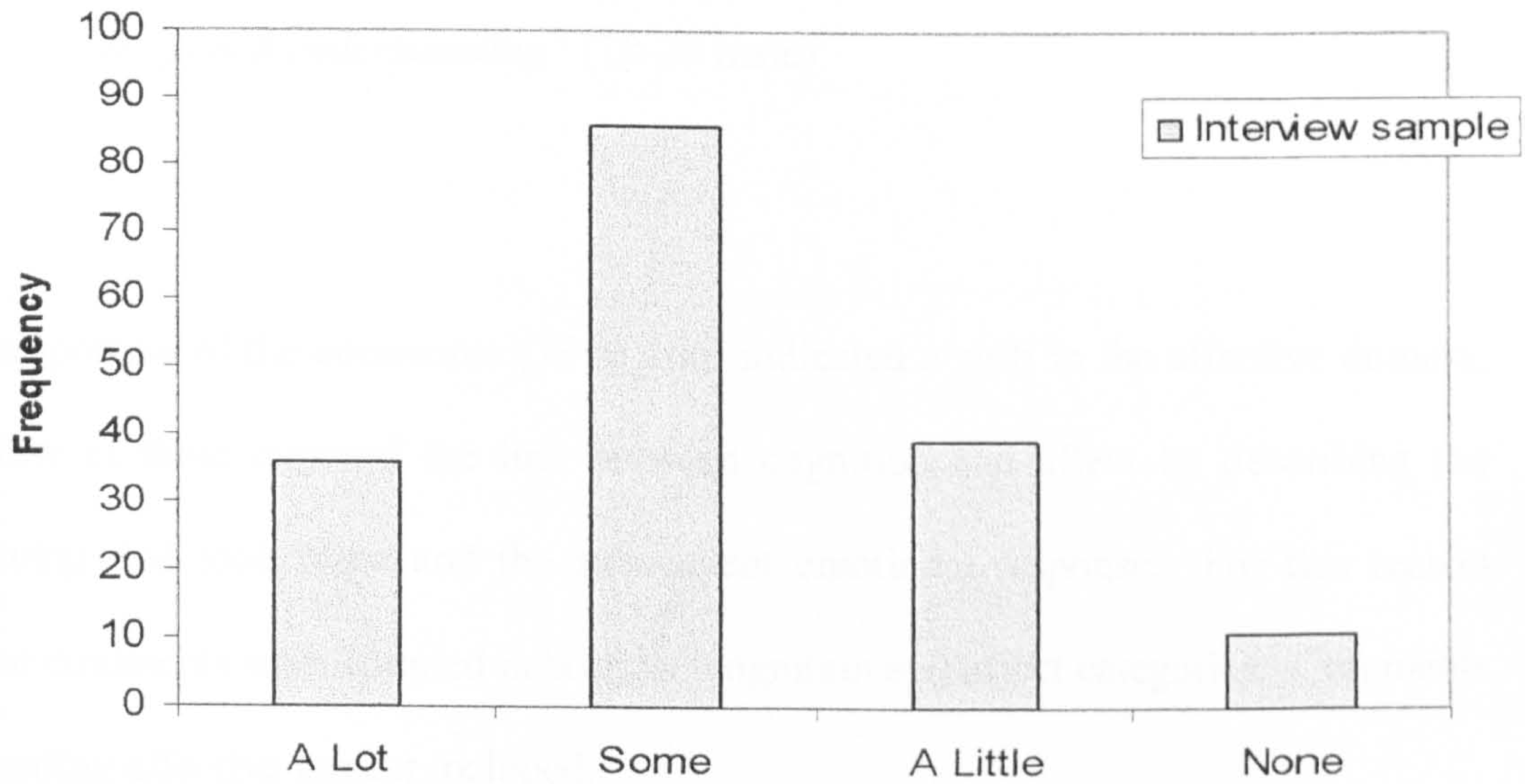
Scientific level of festival events

Members of the audience survey sample were asked if they felt that the speakers communicated on a level appropriate to the audience, and 96% responded in the affirmative. Results obtained from interviews following specific events reinforce this sentiment, as most respondents felt that the science in the events was *'about the right level'*. This suggests that, on the whole, the events were targeted correctly for their audiences.

6.3.6 Impact of the festival on visitors

Cognitive impact of the festival was measured indirectly by asking interviewees how much science they felt they had learned from the festival. The possible responses were: '*a lot*', '*some*', '*a little*' or '*none*'. Figure 7.17 shows the distribution of responses from the interview sample.

Figure 6.6 *Perceived cognitive impact of the festival, responses to the question 'How much science do you feel you have learned from the festival?'*



Only 6% of respondents felt they had learned no science from the festival, and several of these were scientists who gave the reason that their pre-existing science knowledge was reasonably extensive. Combined with the large number of festivalgoers who described the festival as '*educational*', this result indicates that an event such as this has a perceived cognitive impact on its visitors.

Interviewees were asked if attending the festival had changed the way they felt about science and, if so, in what way. 166 comments were collected in this way, and around half (48%) of respondents claimed that the festival had not changed the way they felt about science. However, a number commented that this was due to their existing positive attitude towards science.

Of the remaining comments, 23 indicated a shift in the cognitive domain, these included:

> *"better knowledge and understanding"* (45-54 female)
>
> *"conveys complicated subjects clearly"* (35-44 female)
>
> *"learned new science"* (55-64 female)
>
> *"deepened understanding"* (18-24 male)

A proportion of the comments (39 of 166) indicated a shift in the affective domain. A few of these exposed the link between cognition and affect by describing the learning that took place and the subsequent emotional response. For this reason these comments were counted in both the cognition and affect categories. Comments regarding affective impact included:

> *"it has made it feel more fun"* (18-24 female)
>
> *"scientists change the way we think and live"* (18-24 male)
>
> *"more interested in science"* (under-18 female)
>
> *"realise there is a variety to science – not as boring as [I] thought"* (35-44 female)

A further 13 comments expressed the fact that the festival had reinforced an existing positive attitude towards science, for example:

> *"reinforced like of science"* (35-44 male)
>
> *"rekindled enthusiasm"* (35-44 female)
>
> *"has strengthened interest"* (under-18 male)

It would appear from these comments that the festival as a whole had both cognitive and affective impacts on visitors, whereas the impact of individual events was primarily cognitive. In addition, almost all (99%) festivalgoers agreed that the festival was a *'fun way to learn about science'*.

6.3.7 Dialogue

One of the festival aims was to stimulate discussion of scientific issues amongst festivalgoers. It was difficult to measure whether or not such discussions were taking place, but the interviewees were asked if they had taken part in any debates at the festival, and if they were likely to continue the discussions outside the festival. A quarter of the interviewees (25%) had actively taken part in a discussion, debate or question-and-answer session at the festival (that is, voiced a question, comment or opinion during a *talk*, *debate* or *science café*). When the remaining interviewees were probed as to why they had not taken the opportunity to ask questions of the speakers, the most common response was that no suitable question had come to mind, or that the questions they had before the event had been addressed during the session. A few interviewees admitted to feeling too intimidated to ask questions during the sessions. The majority of respondents (70%) stated that they were likely to discuss issues raised at the festival outside the festival.

6.3.8 Longer-term impact

All of the 43 members of the follow-up survey, conducted by postal questionnaire, expressed a pre-existing interest in science. Most respondents (77%) could recall at least one *talk*, *debate* or activity they attended during the festival 6 months later. They were asked whether they thought the festival had changed the way they felt about science six months after the festival. 13 of the 43 reported that there was no change; of the others, three reported cognitive shifts, 14 reported affective changes and 7 reported that the festival had reinforced their positive attitudes towards science. From these data it appears that the festival impacts detailed above continued for at least 6 months after the festival, although the group of respondents who returned the forms are likely to be those who held positive views of the festival. The high level of engagement of these respondents is typified by the high response rate to the postal survey.

Responses to the follow-up survey also indicated behavioural change – the questionnaire asked whether respondents had been prompted to take any actions following the festival, and many claimed to have bought science books or visited science websites. One respondent said she now takes food supplements as a result of attending the '*Science of Ageing*' presentation. A few respondents also reported visiting museums and science centres, often with their children.

6.4 DISCUSSION

6.4.1 Festival successes

In general, responses to the festival were very positive. The festival was perceived to have good entertainment and educational value, and many festivalgoers left having changed their opinions on issues raised at the festival (as demonstrated by the responses to question 9 in the exit interviews on page 184) and keen to continue the discussion of those issues. A large majority of festivalgoers felt that the events were targeted at the right level scientifically; however some festivalgoers were under the impression that the main target audience of the festival was children. These findings represent successes on the part of the festival organisers and directors, who provided an event that was appropriately designed for, and enjoyed by, those who attended.

6.4.2 Festival impact

The festival had an impact on the cognitive, affective and behavioural domains of its visitors. The impact of an individual event was often limited to a cognitive shift, although the effect of a collection of these events, or the 'festival experience', often led to more positive feelings about science in general, and sometimes an alteration in behaviour.

Interestingly, festivalgoers who had attended the more discursive sessions such as the *science cafés* appeared to leave with less clear changes in opinion than those who attended the less discursive activities such as the lectures. The current trend for emphasising dialogue in science communication activities (House of Lords, 2000) encourages publics to engage with the debates around scientific issues, rather than simply learning new scientific information. The results from the science café visitors indicate that they promote this type of interaction. In addition, several people who contributed to the *science café* events had not taken part in such a discussion before.

One unexpected way of stimulating discussions about festival events was demonstrated with the *'Evolving Art'* project in the *Discover Zone*, where festivalgoers united in a common task (colouring squares of card to form a large image from pixels) struck up conversation about the different events.

6.4.3 Festival limitations

The main limitation of the festival was in the audience it attracted. Gender balance among attendees was roughly equal (which counters the preconception that science is male-dominated) and all age groups were represented, although not equally. However the other festivalgoer demographics revealed that while the festival made every effort to make science accessible, it was not fully inclusive. The typical festivalgoer was a white, middle-aged, member of the ABC1 demographic group with an existing interest in science. They were likely to read 'broadsheet' newspapers, and listen to classical music and current affairs on the radio.

The festival in its current format is not ideally positioned to attract traditional inattentive audiences, who, as described in Chapter 1, often come from less affluent backgrounds and have lower levels of education than their more engaged counterparts. Firstly, any event that is overtly labeled as 'science' will naturally attract first and foremost those who have an existing interest in the topic. Some adults without a pre-existing positive attitude towards science did attend the festival, mostly accompanying a friend, relative or partner. While the impact on these festivalgoers was a strong one, their numbers were few. Secondly, while there were numerous advantages that made locating the festival in Cheltenham a good idea, the local demographic meant that few members of the '*Not Sure*' and '*Not for Me*' groups (as defined in Wellcome/OST, 2000 and summarized in Chapter 1) were likely to attend. However, a large number of retired people visited the festival, and it became apparent in several of the interviews that the festival was accessible to retired females who had not studied much science at school.

The issue of engaging these 'inattentive' audiences is probably the biggest challenge facing science communicators; a solution to this problem will be neither easily found nor straightforward. The difficulty for organisers of events such as science festivals is that attracting audiences without a pre-existing positive attitude towards science requires extra investment of time and finances. This has been recognized by the science communication community, and is currently being addressed through a number of initiatives, for example the Delivering Inclusion in Science Communication (DISC) project (2005). In addition, the BA Festival of Science has recently adapted its programme to include more outreach-type activities held in a variety of venues. Although supported by numerous sponsors, much of the funding for science festivals such as Cheltenham is obtained through ticket sales, and there is simply not room in the budget to invest in engaging hard-to-reach groups. For this reason, and because festivals such as Cheltenham are so successful with the groups they do reach, the question as to whether science festivals are an appropriate medium for engaging inattentive audiences would appear to be an important one.

Appendix 6.1

Data collection materials

- Semi-structured interview schedules (exit and general interviews)
- Audience survey questionnaires
- List of evaluation questions used with personal response system
- Follow-up postal questionnaire

Exit interview

We are interested in your opinions about the event you have just attended. The interview will only take a few minutes and your comments will help us plan future events.

1. How would you rate the event?

☐ Very Good ☐ Quite Good ☐ Neutral ☐ Quite Bad ☐ Very Bad

2. Were you aware that this event was sponsored by Pfizer/Wellcome? Yes No

3. What did you think of the length of the event?

☐ Much Too Long ☐ Too Long ☐ About Right ☐ Too Short ☐ Much Too Short

4. What did you think of the Science in the event?

☐ Much Too Easy ☐ Too Easy ☐ About Right ☐ Too Difficult ☐ Much Too Difficult

5. Did you join in the debate? Yes No

6. Have you taken part in a debate like this before? Yes No

7. Do you feel that your opinion was taken onboard in the session? Yes No

8. Do you think that having attended this session, you would continue to discuss it outside the Festival?
Yes No

9. Has the session changed your opinion on the topic? Yes No If YES, in what way?

10. Do you think that the event was an enjoyable way to learn some Science?

☐ Strongly Agree ☐ Agree ☐ Neither Agree nor Disagree ☐ Disagree ☐ Strongly Disagree

11. How much previous knowledge would you say you had on this topic?

☐ A lot ☐ Some ☐ A Little ☐ None

12. How much Science do you feel you've learned from the event?

☐ A lot ☐ Some ☐ A Little ☐ None

13. What was you favourite part of the session?

14. What was your least favourite part of the session?

15. Can you think of any ways in which an event like this could be improved in the future?

16. Would you attend an event like this again? **Yes** **No**

Festival Evaluation

We are interested in your opinions about this year's Cheltenham Science Festival. The interview will only take a few minutes and your comments will help us plan future events.

1. How many days have you spent/will you spend at the Festival?

☐	☐	☐	☐	☐
1 day	2 days	3 days	4 days	5 days

2. Did you book in advance or drop in?

☐	☐
Book	Drop In

3. Which parts of the Festival have you visited/will you visit?

☐	☐	☐	☐	☐	☐
Discover Zone	Work Shop	Schools	Regular event	dialogue	other

4. Did you attend last year's festival?

☐	☐
Yes	No

5. How did you hear about the Festival?

☐	☐	☐	☐	☐
Came last Year	Newspaper /Magazine	Radio	Word of Mouth	other...................

6. Which part of the Festival have you enjoyed the most? Why?

☐	☐	☐	☐	☐	☐
Discover Zone	Work Shop	Schools	Regular event	dialogue	other

Why?

7. Which part of the Festival have you enjoyed the least?

☐ Discover Zone ☐ Work Shop ☐ Schools ☐ Regular event ☐ dialogue ☐ other

Why?

8. Could you sum up your Festival experience so far in 3 words?

9. Why do you think we have a Science Festival in Cheltenham?

10. Do you think that the Festival is an enjoyable way to learn some Science?

☐ Strongly Agree ☐ Agree ☐ Neither Agree nor Disagree ☐ Disagree ☐ Strongly Disagree

11. How much Science do you feel you've learned from the Festival?

☐ A lot ☐ Some ☐ A Little ☐ None

12. Before you came to the Festival, how did you feel about Science?

☐ Really liked ☐ Quite Liked ☐ Neither Liked Nor Disliked ☐ Didn't Like Much ☐ Really Didn't Like

13. Do you think that the Festival has changed the way you feel about Science? In what way?

14. Whilst at the Festival, have you taken part in any discussions or debates?

☐ Yes ☐ No

15. Have you been prompted to discuss any of the issues raised at the festival outside the Festival?

☐ Yes ☐ No

16. How would you rate the Festival?

☐ Very Good ☐ Quite Good ☐ Neutral ☐ Quite Bad ☐ Very Bad

17. Would you come again next year?

☐ Yes ☐ No

18. How do you think that the Festival could be improved?

Now some questions about yourself...

19. Which of the following age brackets do you fall in?

☐ <18 ☐ 18-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65+

20. Gender ☐ Male ☐ Female

21. Who are you here with?

☐ School ☐ Family ☐ Friends ☐ Alone ☐ Partner ☐ Community Group............... ☐ Other

22. How many people are in your party (including yourself)?....................

23. How many times a year would you say you visit a science centre, science based events or conferences?

☐ 0 ☐ 1 ☐ 2-3 ☐ 4-5 ☐ 6-7 ☐ 8-10 ☐ 10+

24. How many times a month would you say you read the science pages in the national broadsheets or articles in specialist magazines?

☐ 0 ☐ 1 ☐ 2-3 ☐ 4-5 ☐ 6-7 ☐ 8-10 ☐ 10+

25. What is your occupation?

26. What is the first part of your postcode?..

And finally, would you be willing to be contacted at a later date for a possible follow-up interview or questionnaire?

If so, name..

Phone Number/s..

E-mail...

Postal Address

....

....

....

Preferred form of communication

☐ Phone ☐ E-mail ☐ Post

Thanks!

27. *Please complete the following (please rate all those which apply to you):*

	Excellent	*Good*	*Satisfactory*	*Poor*	*Very poor*
Overall impression	[ ]	[ ]	[ ]	[ ]	[ ]
Box office service	[ ]	[ ]	[ ]	[ ]	[ ]
Staff friendliness	[ ]	[ ]	[ ]	[ ]	[ ]
Events/Shows	[ ]	[ ]	[ ]	[ ]	[ ]
Audience involvement	[ ]	[ ]	[ ]	[ ]	[ ]
Range of hands-on exhibits	[ ]	[ ]	[ ]	[ ]	[ ]
Condition of hands-on exhibits	[ ]	[ ]	[ ]	[ ]	[ ]
Atmosphere/room layout	[ ]	[ ]	[ ]	[ ]	[ ]
Disabled access	[ ]	[ ]	[ ]	[ ]	[ ]
Value for money	[ ]	[ ]	[ ]	[ ]	[ ]

28. If you used the cafe or bar during your visit, please complete the following:

	Excellent	Good	Satisfactory	Poor	Very poor
Presentation	[ ]	[ ]	[ ]	[ ]	[ ]
Variety/menu	[ ]	[ ]	[ ]	[ ]	[ ]
Service	[ ]	[ ]	[ ]	[ ]	[ ]
Opening hours	[ ]	[ ]	[ ]	[ ]	[ ]
Value for money	[ ]	[ ]	[ ]	[ ]	[ ]

29. If you could make one improvement to the Festival, what would it be?

____

30. If you could make one improvement to the venue/service, what would it be?

____

Please complete the following if you would like to be entered for our FREE PRIZE DRAW and a chance to win a pass to the events at next year's Festival (terms and conditions apply) NB supplying an email address will help us keep future mailing costs down!:

Name ______________________________
Address ______________________________
____
Postcode ______________________________
Telephone ______________________________
Email ______________________________

If you are not on our mailing list already, we would like to send you information about our events in the future. Would that be all right? Yes [ ] No [ ]

If so, please indicate below the type of events you are interested in (tick as many boxes as you like) and ensure you have filled in your name and address above:

Literature	[ ]	Poetry	[ ]	Comedy	[ ]
Talks/lectures	[ ]	Early music	[ ]	Contemporary classical	[ ]
Chamber music	[ ]	Song recitals	[ ]	Choral	[ ]
Orchestral	[ ]	Opera	[ ]	Folk/Roots/World	[ ]
Trad jazz/blues	[ ]	Modern jazz	[ ]	Rock/pop	[ ]
Brass/military	[ ]	Exhibitions	[ ]	Light entertainment	[ ]
Ballroom dancing	[ ]	Drama	[ ]	Family/children's	[ ]
Contemporary dance	[ ]	*Ballet*	[ ]	*Science*	[ ]

In association with Pfizer

Cheltenham Festival of Science

4 - 8 June 2003

Help us continue the development of Cheltenham Festival of Science and you could win a FREE pass* to the events at next year's Festival!

We are keen to ensure that we maintain the support of our Festival-goers as well as that of local and national businesses. In order to do this, we need to know as much about the profile of our audience as possible.

I would be very grateful, therefore, if you could spare a few minutes of your time to complete this questionnaire. Your feedback is extremely important to us, but please feel free to leave blank those questions you would prefer not to answer.

If you would like to be entered into our FREE PRIZE DRAW to win a pass* to the events at next year's Festival, please fill in your details on the back page.

Please give your completed questionnaire to one of the Festival staff, or leave it in the box at the Festival Information Point on your way out.

Thank you for your time and for supporting the Cheltenham Festival of Science. I do hope you enjoyed your visit and hope to see you next year!

Alison Byard
Sales & Marketing Manager

* Terms and conditions apply

Cheltenham Festival of Science, Town Hall, Imperial Square, Cheltenham, GL50 1QA
Tel: 01242 521621 Visit our website at: www.cheltenhamfestivals.co.uk

Registered Charity no: 251765

[redacted]

[redacted]? Yes [ ] No [ ]

If yes, in what way? (please specify)

3. Do you feel that the speakers communicated on a level appropriate to the audience? Yes [ ] No [ ]

4. How do you think audiences can be best involved in Q&A sessions/debates?

Use of roving mics [ ] Submission of questions prior to the event [ ]

Live voting [ ] Submission of written questions during the event [ ]

Other (please specify)

[redacted] party today (including yourself)?

[redacted] attend today's Festival event(s)?

Home [ ] Visiting friends/relatives [ ] Hotel [ ] B&B [ ]

Other (please specify)

[redacted] your home postcode? [ ][ ][ ][ ]

[redacted] attending Festival events?

1 [ ] 2 [ ] 3 [ ] 4 or more [ ]

[redacted] Festival?

On mailing list [ ]	Flyer [ ]	Word of mouth [ ]
Poster [ ]	Magazine [ ]	Newspaper article [ ]
Radio [ ]	School/College [ ]	Newspaper advertisement [ ]
Television [ ]	Internet [ ]	Science club or society [ ]

Other (please specify)

[redacted]

	0	1	2-3	4-5	6-7	8-10	10+
Museums/Exhibitions	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Science centres	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Other tourist attractions	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Talks/Lectures	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Science events	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
The cinema	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
The theatre	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Rock/Pop concerts	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Classical/Jazz concerts	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

[redacted] from any of the following?

Daily Telegraph [ ] Gloucestershire Echo [ ]

Science related website (please specify)

12. Can you name any of the Festival's sponsors?

Spring Literature [ ] Jazz [ ] Music [ ]

Autumn Literature [ ] Other (please specify)

[redacted] the UK and if so, which? (please specify)

[redacted] Yes [ ] No [ ]

[redacted]

On your own [ ] With a spouse/partner [ ]

With parents [ ] House/flat share [ ]

[redacted] you have?

0 [ ] 1 [ ] 2 [ ] 3 or more [ ]

[redacted] breaks) do you take each year?

1 [ ] 2 [ ] 3 [ ] 4 or more [ ]

[redacted] abroad on business?

0 [ ] 1 [ ] 2 [ ] 3 [ ] 4 or more [ ]

[redacted] Male [ ] Female [ ]

[redacted]

Under 18 [ ] 18-24 [ ] 25-34 [ ] 35-44 [ ]

45-54 [ ] 55-64 [ ] 65+ [ ]

[redacted]

[redacted] Degree [ ] Postgraduate qualification [ ]

[redacted] listen to regularly?

Local newspaper (please specify)

National daily newspaper (please specify)

National Sunday newspaper (please specify)

Magazines (please specify)

National radio station (please specify)

Local radio station (please specify)

[redacted] do you use the internet?

0	1-5	6-10	11-15	16-20	21-25	25+
[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

26. If you would be interested in taking part in a focus group after the Festival please note down your name and a daytime telephone telephone number or email address where we can reach you

more questions overleaf

Electronic voting questions

1. Are you:

Male? Female?

2. In which of the following age groups are you?

Under 18? 18-24? 25-34? 35-44? 45-54? 55-64? 65+?

3. How would you rate the festival?

Very good? Good? Neither good nor bad? Bad? Very Bad?

4. Would you come again next year?

Yes? No?

5. How many times a year would you say you visit a science centre, science based events or conferences?

0? 1? 2-3? 4-5? 6-7? 8-10? 10+?

6. How many times a month would you say you read the science pages in the national broadsheets or articles in specialist magazines?

0? 1? 2-3? 4-5? 6-7? 8-10? 10+?

Cheltenham Festival of Science Evaluation: Follow-Up

Please take a few minutes to complete the questions on this form, and return it in the envelope provided. Your comments will help us plan future events.

1. How do you feel about Science?

☐	☐	☐	☐	☐
Really like	Quite Like	Neither Like Nor Dislike	Don't Like Much	Really Don't Like

2. Do you think that the Festival changed the way you feel about Science? If so, in what way?

3. Which part of the Festival did you enjoy the most? Why?

☐	☐	☐	☐	☐	☐
Discover Zone	Work Shop	Schools	talk/debate	dialogue	other not sure

Why?

4. Which part of the Festival did you enjoy the least?

☐ Discover Zone ☐ Work Shop ☐ Schools ☐ talk/debate ☐ dialogue ☐ other ☐ not sure

Why?

5. Without referring back to any Festival literature, can you recall the names of any speakers or titles of any of the events/activities you attended? If so, please list them below:

6. Please write down 3 words that sum up your Festival experience?

7. Do you think that the Festival is an enjoyable way to learn some Science?

☐ Strongly Agree ☐ Agree ☐ Neither Agree nor Disagree ☐ Disagree ☐ Strongly Disagree ☐ Not Sure

8. How much Science do you feel you learned from the Festival?

☐ A lot ☐ Some ☐ A Little ☐ None ☐ Not Sure

9. Whilst at the Festival, did you take part in any discussions or debates?

☐ Yes ☐ No ☐ Not Sure

10. Did the Festival prompt you to do any of the following...

a) discuss any of the issues raised at the festival outside the Festival?

☐ Yes ☐ No ☐ Not Sure

If so, what can you recall discussing and why?

b) take an action to find out more information, e.g. go to the library, look up information on the internet, buy a book etc.

☐ Yes ☐ No ☐ Not Sure

If so, what action/s did you take and why?

c) attend another Science event or Science attraction, e.g. museum, Science Centre, Science Festival etc.

☐ Yes ☐ No ☐ Not Sure

If so, where did you visit and why?

11. How would you rate the Festival?

☐ Very Good ☐ Quite Good ☐ Neutral ☐ Quite Bad ☐ Very Bad

12. Would you come again next year?

☐ Yes ☐ No ☐ Not Sure

13. Are there any other ways in which you think the Festival has had an impact? If so, please write them below:

14. If you have any other comments on the 2003 Cheltenham Festival of Science, please write them in the space below:

Thanks!

Chapter 7

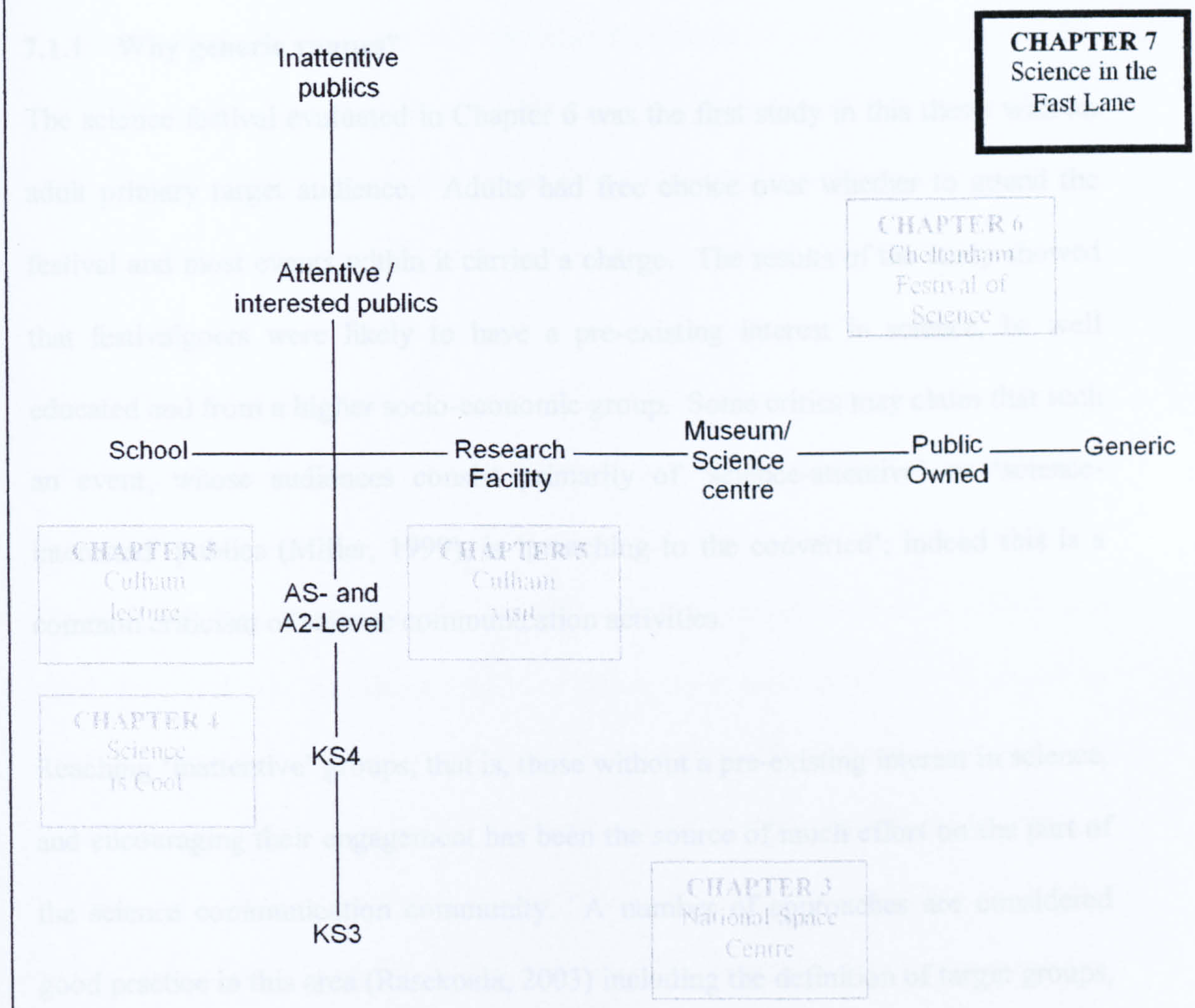
EVALUATION OF THE IMPACT OF AN ACTIVITY IN A GENERIC VENUE ON 'INATTENTIVE' PUBLICS

PAGE

NUMBERING

AS ORIGINAL

Research axes



Horizontal axis shows activity venue, vertical axis shows activity target audience

Chapter 7 considers an activity that was delivered in a generic venue: a motorway service station. The activity included a show involving science tricks, distribution of activity packs, a quiz competition and a website. Data were collected using interviews, questionnaires and observation. The activity successfully engaged a wide range of travellers at service stations, including some people without a pre-existing interest in science.

7.1 INTRODUCTION

7.1.1 Why generic venues?

The science festival evaluated in Chapter 6 was the first study in this thesis with an adult primary target audience. Adults had free choice over whether to attend the festival and most events within it carried a charge. The results of the study showed that festivalgoers were likely to have a pre-existing interest in science, be well educated and from a higher socio-economic group. Some critics may claim that such an event, whose audiences consist primarily of 'science-attentive' or 'science-interested' publics (Miller, 1999), is 'preaching to the converted'; indeed this is a common criticism of science communication activities.

Reaching 'inattentive' groups, that is, those without a pre-existing interest in science, and encouraging their engagement has been the source of much effort on the part of the science communication community. A number of approaches are considered good practice in this area (Rasekoala, 2003) including the definition of target groups, promotion of inclusiveness and ownership, employment of appropriate role models, linking with existing programmes and networks, and outreach. Activities held in generic venues centre on the idea that the activity brings science to members of the public in spaces they use regularly, such as shopping centres, bars, supermarkets and motorway service stations (Burnet, 2002). All publics visit such venues, so there is potential to reach a far broader audience than more traditional science communication activities.

7.1.2 Examples of generic venues activities

Activities in generic venues work best when they are held in a venue where people are likely to be, and where people experience significant '*dwell time*' (Burnet 2002), that is, where they have the time available to engage with the activity. Many generic venues projects are not innovative in the nature of their format; they simply take an existing activity to a new venue with the aim of reaching new audiences.

One of the most well-known examples of science communication activities held in generic venues are Cafés Scientifiques, a movement which started in the UK in 1998 in Leeds and now includes events in 30 towns and cities in the UK, and a number in Europe. The idea came from the French Cafés Philosophiques (Dallas, 1999), and the format typically includes a half hour presentation from a scientist followed by informal discussion held in a café, restaurant or bar. The concept is simple, the opportunity to discuss science in a relaxing and convivial atmosphere has proved popular and audiences are usually large. Indeed, the system is expanding, and Cafés Scientifiques in new towns and cities continue to be organised. The concept has now been developed to include junior Cafés Scientifiques (Gilmore-Stewart, 2004). However, although the venue for such events could be described as a generic one, the audience at such activities have usually visited the venue to participate in the activity, which is advertised beforehand. For this reason, the audience at a Café Scientifique event are unlikely to hold a similar profile of attitudes towards science than the regular venue clientele.

Another generic venues initiative was the '*K-Zone*'. Funded by the Wellcome Trust, it was an interactive exhibition about health issues that toured a number of generic venues, including doctors' waiting rooms, youth clubs and even nightclubs. The success of the pilot in reaching 15-24 year-olds was helped by placing the exhibits in locations popular with the target audience. Nightclubs and youth clubs were particularly successful (Evaluation Associates, 1998). Other successful generic venues projects have included '*Check-Out Science*', a quiz about typical supermarket products, and '*Pub Genius*', a mixture of science tricks and quiz questions aimed at drinkers in pubs (Graphic Science, 2005).

7.1.3 The '*Science in the Fast Lane*' project

The present study evaluates the impact of an activity held in a generic venue; in this case motorway service stations. '*Science in the Fast Lane*' was a pilot project funded by The Committee on the Public Understanding of Science (COPUS) and the Institute of Physics (IoP), targeting families stopping at motorway service stations. It was delivered by the Graphic Science Unit, a science communication consultancy based at the University of the West of England, Bristol. The activity involved erecting a demonstration area at a motorway service station and performing a show consisting of simple yet engaging science tricks, which audience members were then able to reproduce at home. Activity packs were also prepared and distributed to children, with the aim of providing entertainment for long car journeys, and for the adults there was a quiz with a £200 prize. In addition, a website was set up, providing information on how to recreate the tricks, and to offer a forum for discussion of issues raised by the event.

The aim of the project was to encourage a wide audience from all backgrounds to think about the science around them when they travel by car and to explore issues that arise from the application of science in society. It was also intended that the activity would encourage audiences to associate science with helping to solve the problem of keeping travellers occupied on long car journeys. Another aim was to produce a transferable resource in order that the event could be duplicated in any motorway service station. The primary target audience was families, but it was hoped that the event would also appeal to young adults travelling in groups. The event was delivered on three separate occasions, from 10am until 3pm, at three different service stations in southwest England. The activity was evaluated on two of the three days.

7.1.4 The science tricks

Permission for each event was organised in advanced with service station management. In each service station the Graphic Science team erected a stall consisting of a table for the tricks, backed by a colourful display screen bearing a *'Science in the Fast Lane'* banner. A member of the Graphic Science team, Professor Frank Burnet, acted as a Master of Ceremonies and performed the science tricks, gathering a crowd using a microphone and a public address system playing popular music. The tricks performed included: balloon kebab – piercing an inflated balloon with a wooden skewer without bursting it; Alka-Seltzer bomb – exploding a film can using water and an Alka-Seltzer tablet; spinning eggs – using the motion of an egg to determine whether it is cooked or not; lifting lemon – using burning matches to raise the water level in an upturned glass placed in a dish of water on which a lemon slice floats; lager lamp – motion of nuts and raisins in a carbonated liquid; obedient propeller – translation of vibration into rotational motion. The activity packs, or 'goody bags', were aimed at children, but were also given out to other age groups when they requested them. Typical contents of the packs included pens, stickers, sliding puzzles, magnifying rulers, Science Year activities, chemical lights and activity sheets. They were distributed by members of the Graphic Science team. The quiz was aimed at adults, and consisted of a set of multiple choice questions whose answers highlighted issues associated with car travel, like pollution and the flora and fauna found (and not found) on motorway verges. Entrants could either complete the quiz at the service station and hand it back to a member of the team, or complete it at home and return it by post. Either way, completed quiz sheets were entered into a draw to win a £200 prize.

'*Science in the Fast Lane*' toured three motorway service stations during one week in August 2002. The researcher was present on two of the three dates.

7.2 METHODOLOGY

The project was evaluated against the aims described in Section 7.1.3. The event consisted of three different components (science tricks, activity packs and quiz) and it was important to examine the impact of the components separately, as well as assessing the effectiveness of the event as a whole. Five evaluation methods were used. Firstly, face-to-face structured interviews were conducted on two of the three delivery days to evaluate the science tricks. Secondly, questionnaire items were added to the quiz sheets to gather evaluative data. Thirdly, a feedback area was added to the website. Fourthly, observational data were collected by the evaluator on the two days the activity was visited. Finally, media coverage was tracked.

7.2.1 Structured interviews

Interviewing was chosen as the main methodology in order to minimise the sample bias that often occurs with questionnaire-based surveys. The interviews were carried out at random, as opposed to aiming to fill a quota of ages, genders and demographic groups. Only people who stopped to watch the science tricks were interviewed. The interview schedules included both closed- and open-form items, with a view to determining the entertainment and educational value of the tricks and whether the show had an effect on the audience's attitude towards science. In addition, issues to do with the design of the event, e.g. length of show were explored, and audience demographic data were collected.

7.2.2 Questionnaire items

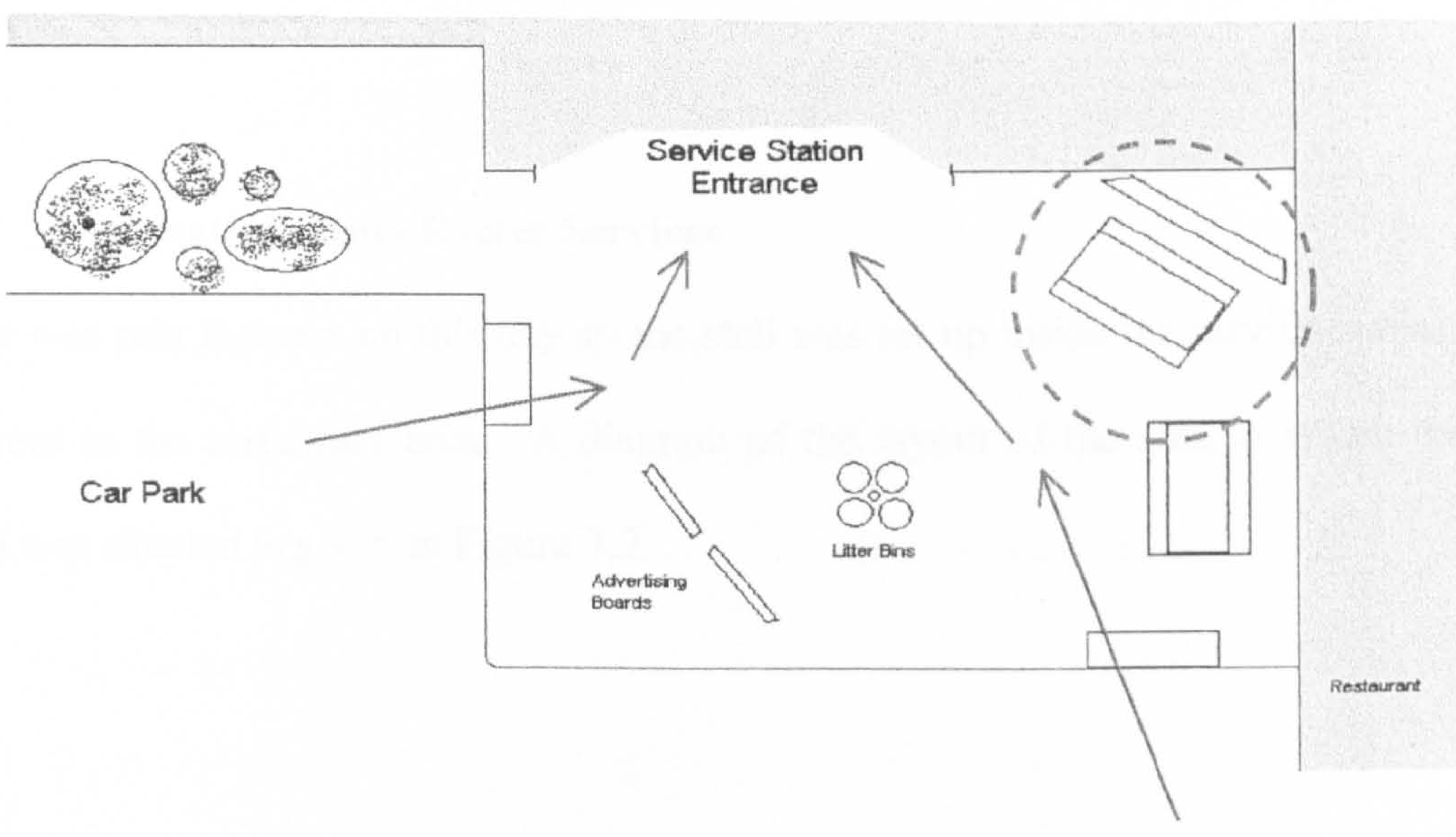
Space on the quiz sheet was limited, so only a few questionnaire items were included. These were designed to judge the response to the activity packs and collected demographic data from quiz entrants. A copy of the evaluation materials is given in Appendix 7.1.

7.3 RESULTS

7.3.1 Observations from Gordano Services

The first delivery day was a weekday so the service station was not as busy as would have been expected at the weekend. The physical arrangement of the activity area is shown in Figure 7.1. The stand (circled) was set up, using a display board and a picnic table, outside the main entrance to the service station. The arrows denote the flow of human traffic past the stall.

Figure 7.1 *Arrangement of activity area*



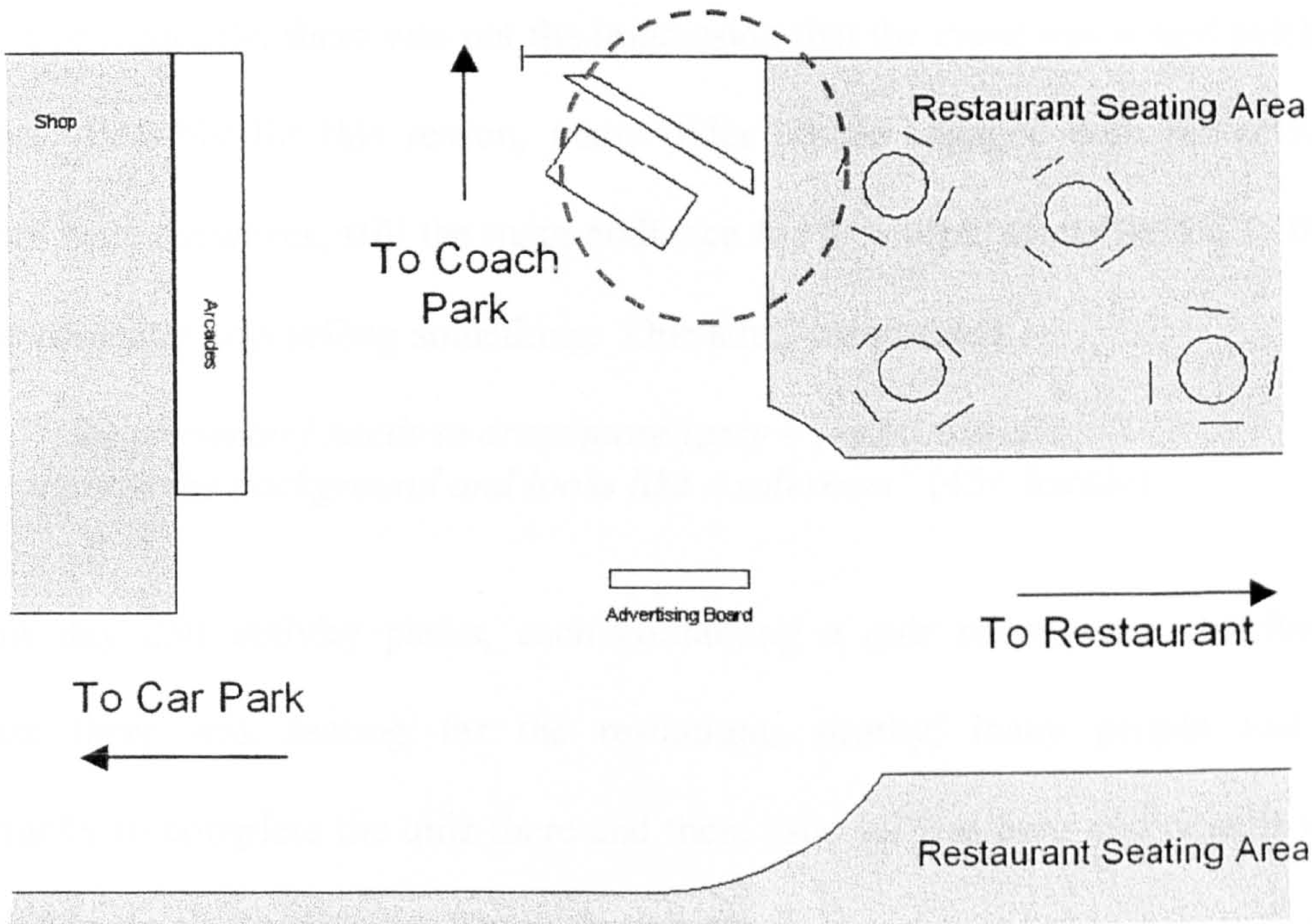
The presenter sought the attention of travellers by approaching them and offering to show them a science trick. Due to the location of the stand, people were passing by and the presenter had only a short time to approach them with the demonstrations. He targeted mainly young children and used the balloon kebab trick to gain their attention. However, once a few people had gathered around the stand, it became easier to attract an audience, and adult family members engaged with the event via the children who were taking part. The other method for drawing attention to the stand was by distributing the activity packs. When the children stopped to be given an activity pack on the way into the service station they were encouraged to visit the stand later to watch a science trick. This approach was effective, as on the way into the services many people were hungry, thirsty or in need of the lavatory. After refreshing themselves, they were more likely to stop and engage with the activity before continuing their journey.

200 activity packs (including quiz sheets) were distributed during the course of the day, including a number to service station staff who requested them for younger relatives.

7.3.2 Observations from Exeter Services

There was rain forecast on this day so the stall was set up inside the service station, adjacent to the restaurant area. A diagram of the layout of the area in which the stand was situated is given in Figure 7.2.

Figure 7.2 *Arrangement of activity area*



The event dynamic at this location was completely different to that at the previous venue. Because the stand was located in an area where people were more static, audience members had a chance to witness the activity before deciding whether or not to engage. This resulted in members of the public approaching the stand, rather than the presenter approaching members of the public. The event worked better where the stand was located at a '*lingering point*', as opposed to the '*thoroughfare point*' where the stand was erected at Gordano.

The second event was held on a Friday, so the service station was full of people travelling to holiday destinations. This led to large audiences of up to approximately 30 people at a time, which served to encourage interest from other people in the service station.

Because of the stand location, the presenter was not approaching children with the tricks. Consequently, there was not the impression that the event was aimed solely at children. Possibly for this reason, many older people engaged with the activity. Children were, however, still the main audience for the event; adults tended to think that the presenter was selling something. One adult commented

> *"[the presenter] needs to dress more jazzy – [he is] blending against the background and looks like a salesman"* (45+ female)

On this day 250 activity packs, each containing a quiz sheet, were distributed. Because there was seating for the restaurants nearby, many people had the opportunity to complete the quiz there and then, especially as pens and pencils were provided in the activity packs. There was an excellent response to the quiz with over 70 of the quiz sheets returned, a far higher number than was anticipated.

No observer was present for the event at Newport. 150 activity packs containing quiz sheets were distributed.

7.3.3 The study cohort

The study cohort is described in Figure 7.3.

Figure 7.3 *The study cohort*

Sample	n	Gender (%)		Age (n)				
		Male	*Female*	*Under 16*	*16-24*	*25-34*	*35-44*	*45+*
Gordano	20	67	33	14	0	1	3	2
Exeter	22	55	45	16	0	1	0	5
Total interviews	42	60	40	30	0	2	3	7
Quiz questionnaire	81	64	36	30	9	11	16	15

Interestingly, a number of over-45s, who were not the anticipated target audience, engaged with the event. There were a larger percentage of the over-45 age group in the audience at the Exeter event because of the stand's location near to the coach park. All of the over-45's interviewed on this day were on a coach trip with friends or family, and welcomed the activity packs to keep them entertained on the journey, or to pass on to younger family members. The 16-24 age group are represented in the quiz sample, but not the interview sample. This could be due to the larger size of the quiz sample, or perhaps young people in this age group were less keen on the more open engagement with the science tricks. Both the interview and quiz sample appear to be male-dominated.

7.3.4 Pre-existing attitudes towards science

Of the 42 interviews conducted over the two days, 24 people felt they either '*quite liked*' or '*really liked*' science, with nine feeling they '*didn't like* [science] *much*' or '*really didn't like*' it. This indicates that members of the 'science-attentive', 'science-interested' and 'residual' publics were represented in the event audience.

7.3.5 Opinions of the activity

Opinions of the science tricks ('*the show*')

When asked what they thought of the show, nobody described it as '*boring*' or '*very boring*'; it is assumed that the people who had this opinion would not have stayed around to watch the tricks, and therefore would not have been interviewed this is likely to have introduced a bias towards those who found the show interesting. A large majority (93%) of respondents described the show as '*interesting*', with 63% describing it as '*very interesting*'. All (100%) of the interviewees agreed that the show was a fun way to learn about science. This shows an overwhelmingly positive response to the science tricks from those who watched them.

Almost all of the interview respondents felt that the show was about the right length (88%) and that the science was at about the right level (90%). This probably reflects the experience of the team who designed the activity. All of the science tricks were popular, and different individuals and age groups had different favourites. For example, the under-16 age group were most likely to cite the egg trick as their least favourite, while older audience members found it much more interesting. This is probably due to the fact that children and young people are not likely to have experienced the problem of remembering which eggs they have and have not boiled, and so this was not grounded in world experience. Younger audiences were more interested in the Alka-Seltzer bomb and the balloon kebab, as these were easy to reproduce and had an element of '*danger*'; they included piercing and explosions.

Opinions of the activity packs

The activity packs were popular with respondents. Of the 81 people who returned quiz sheets, 36 had picked them up, and all of them (100%) described the activity pack as '*interesting*', with 39% saying it was '*very interesting*'. When asked why they liked the packs, some of the responses were as follows:

> *"Because they had loads of goodies!"* (9-year-old male)
>
> *"Lots of interesting things to do"* (8-year-old female)
>
> *"On a long travel to Devon. Quite bored, I like science when its fun and it'll be a good read and will help me at school"* (12-year-old male)

At least for the young male who gave the last comment, science appears to have been used to solve the problem of boredom on long car journeys, which was one of the project objectives.

7.3.6 Project website

The project aimed to encourage its audiences to explore issues related to the application of modern technology in society. The project website was designed to facilitate this discussion, although it received few visits, probably due to lack of publicity. Some attempts to start such a discussion on the website forum were made by the project team, but received little response. The website was publicised on the event stand, and the web address printed on the quiz sheets and other project materials. However, in order to sustain a reasonable number of visits, websites must be highly publicised, and the project budget could not accommodate this.

7.3.7 Opinions of the project aims

During the interviews, audience members were asked what they thought the aim of the event was, and whether they thought it had been fulfilled. Some of the responses were as follows:

> *"To make people more aware and think about science"* (35-44 male)
>
> *"To show science can be fun and not boring"* (35-44 female)

A large proportion of the responses included the terms '*aware*', or '*think about*' in relation to science. Indeed, raising awareness of the science around people when they travel by car was one of the project aims. However none of the respondents recognised that the science being presented to them in the show was related to car travel, although the quiz questions were clearly related. However, not everyone who watched the show participated in the quiz, so this may need to be given greater emphasis in the future.

7.3.8 Cognitive impact

Interviewees were asked how much science they felt that they had learned from the show. Three-quarters of respondents (76%) felt they had learned at least '*some*' science from the show, with 40% claiming they had learned '*a lot*' of science. Only one respondent said that he had learned no science. Considering few respondents spent more than 15 minutes watching the tricks, this activity appears to have significant educational value.

7.3.9 Affective impact

Nearly two thirds of people interviewed (64%) said that the event had changed the way they felt about science, and all but one of these people said that they liked science more having seen the tricks. When asked why, some of the responses were:

> *"He* [the presenter] *is more fun than a teacher, and I'm not in school!"* (11-year-old female)
>
> *"It seems more fun and exciting"* (11-year-old male)
>
> *"It made me more aware – I didn't do much science at school"* (over 45 male)

The first comment is indicative of the negative attitudes towards 'school science' described in Chapter 1.

7.3.10 Activity media coverage

The event generated local newspaper and radio coverage. The radio coverage had the greatest impact, as the interview was broadcast in the area on the morning of the first delivery day. Several audience members commented that they had heard about the event on the radio and decided to come along.

7.4 DISCUSSION

The *Science in the Fast Lane* project ran smoothly with good organisation and no major problems. There was a positive response to the event both from interviewees and quiz entrants. The activity packs were popular, all 600 were distributed over the course of the three days. The event appeared to succeed in making people more aware about science facts in general. However, it appears that greater emphasis on where the science covered fitted in with car travel is needed. In future it is suggested that when explaining the science behind the tricks, more time is taken to show how the phenomena demonstrated are related to car travel. It may also be worthwhile to incorporate into the stand backdrop a poster explaining that the science tricks are relevant to car journeys. This may then encourage the audience members to ask questions about how the science relates to car travel, thereby stimulating a discussion.

The activity appeared to succeed in engaging its primary target audience, bored children on car journeys. It also seemed to interest a range of other groups, including senior citizens on coach trips, service station staff and army cadets. The fact that the *Science in the Fast Lane* event incorporates different types of activity helped it reach different audiences. For example, the 16-24 year-olds who seemed unlikely to take part in the science tricks were still interested in the quiz. The activities were initially targeted at different age groups, but this was not borne out in those who participated, for example plenty of older audience members were interested in the show, and many children completed the quiz. This indicates that it may not have been sufficiently emphasised that the quiz was aimed at adults. Unfortunately, some of the children who attempted it may have found it discouraging because the questions were above their ability. It would be helpful if there was a message at the top of the quiz sheet explaining that it was aimed at an older age group, or advising children to seek help from an adult.

The generic venue of the service station appeared to work well. Service stations are often dull places, and enjoyable activity was a welcome distraction for travellers. The location of the *Science in the Fast Lane* stand was important. There was a great deal of difference in the number of people who stopped to watch the tricks and complete the quiz when the stand was located at a *'lingering point'* (Exeter), as opposed to a *'thoroughfare point'* (Gordano). The day of the week the event was held on made a difference to the number of people who participated. The service stations are busiest on Fridays and at weekends, as this is when many people choose, or have the opportunity, to travel for recreational (rather than business) purposes.

The *Science in the Fast Lane* website was not considered successful in promoting discussion of issues related to the event. This might have been due to the time of year of the event; many young people may only have internet access at school or college, so would not be able to visit the website during holiday times. Even if young people have internet access at home, many people who participated in the event were travelling to a holiday destination, where they are unlikely to use a computer.

Generally, the activity appeared to have a high level of cognitive and affective impact on those who engaged with it. By using a generic venue, the project engaged a number of individuals who did not have a pre-existing interest in science, and may therefore be unlikely to attend an event such as Cheltenham Festival of Science.

Appendix 7.1

Data collection materials

- Interview schedule
- Questions included on quiz sheet

Science in the Fast Lane – Interview Questionnaire

We are interested in your thoughts about today's event. The interview will take 3-4 minutes and will help us plan future events.

Did you see the show?

☐	☐
Yes	No

What did you think of the ***Science in the Fast Lane*** show?

☐	☐	☐	☐	☐
Very Interesting	Quite Interesting	Neither Interesting nor Boring	Quite Boring	Very Boring

What did you think about the ***length*** of the show?

☐	☐	☐	☐	☐
Much Too Long	Too Long	About Right	Too Short	Much Too Short

What did you think about the ***Science*** in the show?

☐	☐	☐	☐	☐
Much Too Easy	Too Easy	About the Right Level	Too Difficult	Much Too Difficult

Did you think the show was a ***fun way*** to learn some Science?

☐	☐	☐	☐	☐
Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree

How much Science did you learn from the show?

☐	☐	☐	☐
A Lot	Some	A Little	None

How did you *feel* about Science before today?

☐ Really Liked ☐ Quite Liked ☐ Neither Liked nor Disliked ☐ Didn't Like Much ☐ Really Didn't Like

Do you think that today's event has ***changed*** your attitude towards Science?

☐ Yes ☐ No

If so, in what way and why?

What do you think the ***aim*** of this event is?

Has the aim been fulfilled?

☐ Yes ☐ No

What did you think of the show and why?

What was your ***favourite*** part of the show and why?

What was your *least favourite* part of the show and why?

How do you think that this event could be improved in the future?

Some information about yourself...

Age .... ☐ Under 25 (please state age) ☐ 25-34 ☐ 35-44 ☐ 45+

Gender ☐ Male ☐ Female

Who are you here with?

☐ Alone ☐ Partner ☐ Family ☐ Friends ☐ Work Colleagues ☐ Other (please state) ....

What is the purpose of your journey?

☐ Day out ☐ Holiday ☐ Business ☐ Visiting Family/Friends ☐ Other (please state) ....

How long is your journey in miles? ☐ Miles

Thank-you

Quiz sheet questions

Age: ☐ Under 25 (please state age)................ ☐ 25-34 ☐ 35-44 ☐ 45+

Sex: ☐ Male ☐ Female

If you picked up a ***goody bag***, what did you think of the activities?

☐ Very Interesting ☐ Interesting ☐ Boring ☐ Very Boring

Please tell us why:

Chapter 8

META-ANALYSIS: COMPARISON OF THE IMPACTS OF DIFFERENT ACTIVITIES

8.1 INTRODUCTION

A series of science communication activities have been individually evaluated in the preceding chapters. The present discussion considers these results in parallel. The first part of this chapter considers the baseline data collected from Years 8 and 10, and AS- and A2-Level Physics students regarding pre-existing attitudes towards physics. The second part considers the impacts of activities aimed at school students, and will include both the direct and indirect measures of attitude towards physics and understanding of physics. The third section will include the activities aimed at public and family audiences.

8.2 METHODOLOGY

8.2.1 Comparison of pre-existing attitudes

The attitudinal data collected at the first stages of the before-and-after studies provided an insight into students' pre-existing attitudes towards physics. The descriptive data from Chapters 3, 4 and 5 (the chapters considering activities targeted at school students) are presented alongside one another in Section 8.3.1. Differences in responses between males and females were also considered.

8.2.2 Comparison of activities

The schools activities evaluated in Chapters 3, 4 and 5 were compared using the difference in students' responses to the attitudinal indicators, and their scores in the knowledge quiz, before and after the intervention. The attitudinal indicators were measured on a 5-point Likert scale, as described in Chapter 2. New variables were computed by subtracting the second response to the statements from the first, leaving a positive score for a shift towards agreeing with each statement, and a negative score for a shift towards rejection of the statement. The 'mean shift' was then calculated for the attitudinal statements relating to the nature of physics (whether students like physics, whether they perceive it as interesting, boring or relevant). The difference in quiz scores was also calculated. Significant differences in the data were explored using the Wilcoxon signed ranks test, which tests for differences in ordinal data. Impacts on male and female students were considered separately where sample sizes were sufficient.

All activities were compared using students' and publics' responses to the indirect measures of cognitive and affective impact, i.e. self-perceived learning and attitudinal change. This comparison was descriptive rather than statistical, and considered differences between males' and females' responses where sample sizes were large enough to provide meaningful results.

8.2.3 Relationships between indicators

In order to explore the relationship between the indirect and direct indicators, the indirect indicators were recoded into two responses, '*affirm*' and '*reject*', and two corresponding, independent samples created. The distribution of responses to the direct indicators was compared between the independent samples using the Mann-Whitney test, an equivalent of the t-test suitable for use with ordinal data.

8.3 RESULTS

8.3.1 Attitudes towards physics of Year 8 and 10, AS- and A2-Level Physics students

The study cohort

The data from chapters 3, 4 and 5 were used for this analysis. The sample numbers and demographics are given in Figure 8.1 below:

Figure 8.1 *The attitudinal study cohort*

Sample	n	Male %	Female %
Year 8 students	175	49	51
Year 10 students	460	49	51
AS- and A2-Level Physics students	293	77	23

Self-perceived ability and museum visits

Figure 8.2 shows the proportion of students who often visited museums and science centres outside school, and who rated their physics ability as good

Figure 8.2 *Self perceived ability and museum visits*

	Year 8		Year 10		AS & A2	
	Male%	*Female%*	*Male%*	*Female%*	*Male%*	*Female%*
Often visit museums and science centres	17	9	4	6	6	1
Rate physics ability as good	42	31	37	16	60	43

Males appeared to be more likely to visit museums and science centres often in Year 8, although the nature of the scale for this question was such that the middle response was 'sometimes' so the interpretation of the question was somewhat subjective. More interestingly, males were considerably more likely to rate their physics ability as good than females, especially in Year 10. Previous research has identified that males are often more confident in their abilities than females (Stadler *et al*, 2000), and it is likely that this confidence is reflected in the above result.

Nature of the subject

Figure 8.3 shows the percentage of males and females in each group who agreed with a set of statements pertaining to the nature of physics:

Figure 8.3 *Agreement with statements relating to the nature of physics*

	Year 8		**Year 10**		**AS & A2**	
	Male%	*Female%*	*Male%*	*Female%*	*Male%*	*Female%*
Like physics	35	27	48	25	81	75
Interesting	55	39	46	28	88	81
Boring	23	18	25	38	9	7
Relevant to everyday life	59	36	40	32	49	54

In Year 8, male students were more likely than female students to agree that physics is interesting and relevant, and that they *'liked physics'*. However, they were also more likely to agree that physics is a boring subject. This indicates that the male respondents may have held more polarised views of physics than female respondents. More Year 10 males than Year 8 males claimed to *'like physics'*, although the percentage of females feeling this way decreased slightly. Males are also less likely to agree that physics is interesting in Year 10 than Year 8. A decline in attitudes amongst females is evident in the responses to the statements *'physics is an interesting subject'* and *'physics is a boring subject'*, with females less likely to accept the notion that physics is interesting and more likely to accept the notion that it is boring in Year 10 than in Year 8. Respondents of both genders were less likely to agree with the statement *'the things I learn in physics relate to my everyday life'* in Year 10 than in Year 8, however the greater difference was with the males for this statement. AS- and A2-Level Physics students have elected to study the subject post-16, so are likely to report an interest in the subject. It is interesting to note that amongst the AS- and A2-Level physics students, males appear to like physics more and find it more interesting than their female counterparts. Female AS and A2 students were more likely to agree that physics holds relevance to everyday life, so perhaps this is a more important factor to females in electing to study the subject than its inherent interest.

Academic demands of the subject

Figure 8.4 shows the proportion of students who agreed with a set of statements regarding the academic demands of physics.

Figure 8.4 *Agreement with statements relating to the academic demands of physics*

	Year 8		Year 10		AS & A2	
	Male%	*Female%*	*Male%*	*Female%*	*Male%*	*Female%*
Easy subject	13	11	13	5	15	4
More about remembering facts than understanding ideas	21	11	24	23	11	9
Requires mathematical skills	38	42	53	58	73	75

Few students in any of the samples agreed that physics is an easy subject, although males were more likely to agree in Year 10 and AS and A2 than females. Fewer Year 8 females felt that physics was more about '*remembering facts than understanding ideas*', although this had balanced between the sexes in Year 10. The proportion dropped amongst the AS and A2 students, presumably due to the deeper level of understanding required for the AS and A2 physics courses. The proportion of students agreeing that physics requires mathematical skills increased with the age of the students. This is likely to be due to the increased level of mathematics required as the physics becomes more difficult later in the curriculum. Approximately equal proportions of males and females agreed with the statement within each year group.

Types of student

Figure 8.5 shows the proportion of students who agreed with a set of statements regarding types of physics student.

Figure 8.5 *Agreement with statements relating to types of physics student*

	Year 8		**Year 10**		**AS & A2**	
	Male%	*Female%*	*Male%*	*Female%*	*Male%*	*Female%*
Boys' subject	6	7	8	11	26	12
Girls' subject	5	1	2	2	0	3
People who don't mix well	6	3	10	6	8	0

Few students in any of the samples agreed with the statements regarding the types of students who choose physics. The only exception was the AS- and A2-Level males, who were most likely to agree that '*physics is more of a boys' subject*'. This is perhaps understandable given that this sample was 78% male, and many attended boys' schools (although some attended girls' schools). These students may have agreed with this notion because their classes are male-dominated. Few students felt that physics was '*more of a girls' subject*', and more males than females agreed that '*people who like physics don't mix well with others*' in all three samples, although the proportion of males agreeing with this statement was never higher than 10%.

Communication of the subject

Figure 8.6 shows the proportion of students who agreed with two statements regarding the communication of physics

Figure 8.6 Agreement with statements relating to the communication of physics

	Year 8		**Year 10**		**AS & A2 physics**	
	Male%	*Female%*	*Male%*	*Female%*	*Male%*	*Female%*
Uses lots of difficult words	55	37	31	40	19	16
Uses easy, everyday words with different meanings	23	19	22	15	16	28

There was a reasonably even spread of responses to these statements, the main exception being the majority of Year 8 males who agreed that physics uses difficult words. In Year 10, however, more females than males agreed with this statement, and at AS and A2 level the proportions were similar. More males than females felt that physics uses '*easy, everyday words with different meanings*' in Years 8 and 10, however this trend was reversed for the AS- and A2-Level students, where more females than males felt that the language used in physics was accessible.

8.3.2 Comparison of impact of activities

Figure 8.7 shows the samples used for the remaining analysis in this chapter. Firstly, the schools interventions are compared using the direct indicators (attitudinal tracking statements and knowledge quiz). Secondly, responses to the indirect (self-reported knowledge and attitude shifts) and dependent indicators are compared for the school groups. Thirdly, all activities are compared using the indirect indicators.

Figure 8.7 The study cohort

Sample	n	Male %	Female %
Year 8 students – National Space Centre visit	175	49	51
Year 10 students – '*Science is Cool*' lecture	460	49	51
Years 12 & 13 physics students – '*Great Balls of Fire*' lecture	261	82	18
Years 12 & 13 physics students – Culham Science Centre visit	45	53	47
Attentive publics – *Cheltenham Festival of Science*	186	48	52
Inattentive publics – '*Science in the Fast Lane*'	42	60	40

Figure 8.8 shows the shifts in attitude and understanding measured directly for the schools-based activities. The Culham visit sample was not separated by gender because the sample size was too small to allow a meaningful analysis. The results were compared using the Wilcoxon signed ranks test. Only the attitude shifts relating to the nature of physics are presented.

Change in perceptions of physics

From the results it appears that the visit to the National Space Centre was the intervention which had the greatest impact on students' attitudes towards physics.

Figure 8.8 *Comparison of direct measurement of schools activities' impacts*

	Year 8 – Space Centre				***Year 10 – Science is Cool***				***AS & A2 – Great Balls of Fire***				***AS & A2 – Culham visit***	
	Males		***Females***		***Males***		***Females***		***Males***		***Females***		***Males & Females***	
	Shift	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*
Attitudes														
Like physics	0.38	0.00*	0.31	0.00*	-0.11	0.07	0.11	0.03*	0.14	0.87	-0.13	0.08	-0.04	0.71
Interesting	0.12	0.27	0.27	0.00*	0.02	0.77	0.10	0.06	-0.08	0.04*	-0.02	0.74	-0.11	0.24
Boring	-0.27	0.02*	-0.17	0.04*	0.07	0.34	-0.09	0.10	0.03	0.70	0.00	1.00	-0.14	0.21
Relevant to everyday life	0.04	0.82	0.10	0.21	0.15	0.02*	0.08	0.19	0.05	0.43	0.00	1.00	0.02	0.80
Understanding														
Difference in quiz scores	1.42	0.00*	0.97	0.00*	0.22	0.10	0.21	0.01*	1.90	0.00*	1.20	0.00*	1.35	0.00*

'Shift' is the mean difference between students' responses to the attitudinal tracking statements before and after each intervention. A positive figure indicates a shift towards acceptance of the statement, a negative figure indicates a shift towards rejection of the statement

** denotes difference in distribution significant at the 95% confidence interval or higher. Measured using the Wilcoxon signed ranks test*

Significantly more students of both genders claimed to like physics following the visit, and reject the notion that physics is boring. Following the intervention, females were significantly more likely to agree with the notion that '*physics is an interesting subject*' following the intervention, while there was no significant shift for males. However, the males in the sample were more likely to agree that physics was interesting before the intervention (55%) than females (39%). There was no significant shift in students' perceptions of the relevance of physics – possibly due to the nature of the space science (and especially the show '*The Planets*') presented during the intervention.

The impacts of the demonstration lecture were interesting when analysed by gender: there was a negative shift in liking physics for males (not quite reaching the level of statistical significance), but a significant positive shift in liking physics for females. Year 10 girls were also more likely to agree that physics is an interesting subject, and reject the idea that it is boring after the intervention; however these shifts did not quite reach the level of statistical significance. This indicates that the changes were more subtle than those recorded for the Year 8 students who visited the National Space Centre. Males were significantly more likely to accept the notion that '*the things I learn in physics relate to my everyday life*' after the lecture than beforehand.

For the AS and A2 students, the only significant shift was for males who saw the '*Great Balls of Fire*' lecture. These students were more likely to reject the notion that physics is interesting after the lecture than before. There was a negative shift in females liking physics following the lecture, although the shift did not reach significance. However, these students held positive attitudes towards physics before the lecture, and there was no facility on the five-point Likert scale to record whether strong positive responses had grown stronger – in this way noise in the data could be interpreted as a negative shift in attitude.

Change in physics understanding

In terms of educational value, all of the interventions showed a significant improvement in the knowledge quiz scores following the interventions. The exception to this trend was the Year 10 males, whose improvement in test scores was not significant at the 95% level. This suggests that all the interventions are successful in communicating factual physics knowledge to students in the short term at least.

8.3.3 Relationships between direct and indirect indicators

Year 8 students

The results of the analysis for Year 8 students who visited the National Space Centre are shown in Figure 8.9. These results indicate that for the Year 8 students, self-reported change in the way they felt about physics following the activity was a predictor for a positive shift in liking physics, agreeing that it is interesting, and rejecting the notion that it is boring. Those students who found the activity interesting were also significantly more inclined to like physics and agree that it is interesting following the intervention. Those who rejected the idea that the activity was interesting were more likely to say they liked physics less and reject the notion that it is interesting following the activity. Those who felt the science was pitched at an appropriate level were also more likely to agree that physics was interesting and reject the idea that it is boring. There appeared to be a link between those students who agreed that the activity was a fun way to learn, and liking physics more following the activity. This did not reach the level of statistical significance, and therefore appears to be a less powerful indicator of affective impact than self-perceived attitude shift or finding the activity interesting.

Figure 8.9 *Comparison of indicators for Year 8 students who visited the National Space Centre*

Indirect indicators		***Direct indicators***									
		Like physics		Interesting		Boring		Relevant		Dif. in quiz scores	
		Shift	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*
Affect											
Attitude shift	*Affirm*	0.59	0.00*	0.44	0.01*	-0.38	0.04*	0.07	0.93	1.71	0.01*
	Unsure/Reject	0.22		0.06		-0.13		0.07		0.90	
Interesting activity	*Affirm*	0.41	0.02*	0.25	0.03*	-0.21	0.98	0.08	0.48	1.19	0.68
	Neutral/Reject	-0.17		-0.33		-0.28		-0.06		1.33	
Fun way to learn	*Affirm*	0.41	0.06	0.23	0.34	-0.17	0.76	0.06	0.81	1.28	0.57
	Neutral/Reject	0.12		0.05		-0.31		0.10		0.94	
Cognition											
'Some' physics learned	*Affirm*	0.39	0.22	0.22	0.20	-0.20	0.96	0.06	0.90	1.30	0.38
	Reject	0.24		0.11		-0.26		0.09		0.95	
Scientific level of activity appropriate	*Affirm*	0.40	0.10	0.26	0.05*	-0.31	0.01*	0.13	0.11	1.23	0.55
	Reject	0.16		-0.03		0.14		-0.14		1.07	

'Shift' is the mean difference between students' responses to the attitudinal tracking statements before and after each intervention. A positive figure indicates a shift towards acceptance of the statement; a negative figure indicates a shift towards rejection of the statement. E.g., for students who reported an attitude shift ('affirm') there was a mean shift of 0.59 of a Lickert scale point towards liking physics. For students who did not report a shift ('unsure/reject') the shift was 0.22 of a Lickert scale point. The difference in distribution had a p value of 0.00 measured using the Mann-Whitney test.

* *denotes difference in distribution significant at the 95% confidence interval or higher. Measured using the Mann-Whitney test*

Surprisingly, the only indirect indicator that showed a significant link with an improved quiz score following the activity was the self-reported attitude shift. This suggests a link between the cognitive and affective impacts of a visit to the National Space Centre.

Year 10 students

The same analysis was conducted with the data from the Year 10 students who saw the *'Science is Cool'* lecture. The results are presented in Figure 8.10. As discussed earlier in this chapter, the impact of the demonstration lecture on Year 10 students appeared to be weaker than the impact of the National Space Centre visit on the Year 8 students. However, some statistically significant differences in the data were present. For these students, the indirect variable that appeared to be most closely linked to changes in attitude measured directly was whether or not the lecture was deemed interesting. Students who found the lecture interesting were significantly more likely to agree that they liked physics and that it was interesting, and reject the notion that it is boring. For these three direct variables, it is interesting to note the polarity of the means. Students who rejected the notion that the activity was interesting also said they disliked physics more following the lecture, and were more likely to accept that physics is boring and reject the idea that it is interesting. Students who felt that the science in the lecture was either '*too easy*' or '*too difficult*' were more likely to experience a negative shift in liking physics. As with the Year 8 students, no independent variables were significantly linked to an improvement in quiz scores. However, those students who felt that they had learned at least '*some*' physics from the lecture were more likely to say that they liked physics afterwards than before. This indicates a link between the cognitive and affective impacts of the 'Science is Cool' lecture on Year 10 students.

Figure 8.10 Comparison of indicators for Year 10 students who saw the 'Science is Cool' lecture

Indirect indicator		*Like physics*		*Interesting*		*Boring*		*Relevant*		*Dif. in quiz scores*	
		Shift	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*
Affect											
Attitude shift	*Affirm*	0.08	0.24	0.15	0.17	-0.32	0.02*	0.28	0.35	0.34	0.60
	Unsure/Reject	-0.02		0.03		0.02		0.09		0.22	
Interesting activity	*Affirm*	0.05	0.01*	0.07	0.02*	-0.07	0.00*	0.13	0.43	0.26	0.62
	Neutral/Reject	-0.18		-0.09		0.21		0.03		0.06	
Cognition											
'Some' physics learned	*Affirm*	0.06	0.03*	0.06	0.31	-0.04	0.36	0.16	0.23	0.33	0.35
	Reject	-0.09		0.02		0.03		0.06		0.08	
Scientific level of activity appropriate	*Affirm*	0.02	0.02*	0.06	0.57	-0.05	0.25	0.12	0.81	0.28	0.37
	Reject	-0.16		-0.03		0.16		0.12		-0.05	

'Shift' is the mean difference between students' responses to the attitudinal tracking statements before and after each intervention. A positive figure indicates a shift towards acceptance of the statement; a negative figure indicates a shift towards rejection of the statement. E.g., for students who reported an attitude shift ('affirm') there was a mean shift of 0.08 of a Lickert scale point towards liking physics. For students who did not report an attitude shift ('neutral/reject') the shift was 0.02 of a Lickert scale towards disliking physics. The difference in distribution had a p value of 0.24 measured using the Mann-Whitney test.

** denotes difference in distribution significant at the 95% confidence interval or higher. Measured using the Mann-Whitney test*

AS- and A2-Level students

The same analysis was conducted with the data from the Year 12 and 13 AS- and A2-Level students who saw the *'Great Balls of Fire'* lecture. The sample size for students visiting Culham Science Centre was too small to allow a meaningful analysis, so has not been included in the present results. The results are presented in Figure 8.11. As discussed in section 8.3.2, the impact of the *'Great Balls of Fire'* lecture on its target audience was not as strong as the other two interventions considered in this section. Probably for this reason, there are few significant differences between the samples. Students who did not find the lecture interesting were less likely to agree they liked physics after the lecture than before. Those students who felt that the physics in the lecture was pitched at an appropriate level were more likely to agree that *'the things I learn in physics relate to my everyday life'* following the lecture. Interestingly, two of the indirect indicators appeared linked to improved scores in the knowledge quiz. Students who felt they had learned at least *'some'* physics from the lecture, and who felt that the scientific level of the lecture was appropriate performed significantly better in the knowledge quiz following the lecture. This supports the data in Chapter 5, which found that the lecture had an impact on the cognitive domains of its target audience. From the above analysis, it appears that the most powerful indirect indicators for affective impact are self-perceived attitude shift and perception of the activity as interesting. Appropriately pitched scientific content was also a useful indicator of affective impact.

Figure 8.11 Comparison of indicators for AS and A2-Level Physics students who saw the 'Great Balls of Fire' lecture

Indirect indicator		***Like physics***		***Interesting***		***Boring***		***Relevant***		***Dif. in quiz scores***	
		Shift	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*	*Shift*	*p*
Affect											
Attitude shift	*Affirm*	0.06	0.26	0.09	0.25	0.06	0.71	0.00	0.89	1.30	0.74
	Unsure/Reject	-0.04		-0.08		0.02		0.01		1.24	
Interesting activity	*Affirm*	0.02	0.05*	-0.04	0.24	0.00	0.93	0.02	0.82	1.30	0.46
	Neutral/Reject	-0.16		-0.16		0.00		-0.03		1.03	
Cognition											
'Some' physics learned	*Affirm*	-0.02	0.82	-0.06	0.91	-0.01	0.63	0.03	0.61	1.41	0.01*
	Reject	-0.02		-0.04		0.03		-0.01		0.93	
Scientific level of activity appropriate	*Affirm*	-0.02	0.40	-0.04	0.37	-0.01	0.43	0.07	0.01*	1.42	0.00*
	Reject	0.05		-0.11		0.06		-0.14		0.73	

'Shift' is the mean difference between students' responses to the attitudinal tracking statements before and after each intervention. A positive figure indicates a shift towards acceptance of the statement; a negative figure indicates a shift towards rejection of the statement. E.g., for students who reported an attitude shift ('affirm') there was a mean shift of 0.06 of a Lickert scale point towards liking physics. For students who did not report an attitude shift ('neutral/reject') the shift was 0.04 of a Lickert scale point towards disliking physics. The difference in distribution had a p value of 0.26 measured using the Mann-Whitney test.

** denotes difference in distribution significant at the 95% confidence interval or higher. Measured using the Mann-Whitney test*

Self-reported learning only appeared to correlate with the measured improvement in factual knowledge for the AS and A2 students. This might be because it was impossible to test all of the knowledge that students gained during the intervention within the quiz. This is especially true of the National Space Centre visit, where students were present for an entire day, and the breadth of knowledge and skills available for students to learn was considerable. Several students commented on the team working skills they had gained following the simulated Challenger mission, yet there was no facility for measuring this aspect of learning within the data collection instrument. For this reason, students may have rated their own learning highly, whether or not they performed well in the knowledge quiz.

8.3.4 Comparing all activities

Having explored links between the direct and indirect measures of impact, it is now possible to compare all of the interventions using the indirect indicators alone. Figure 8.12 shows the results for the indirect measures of impact for the schools and public audience activities. Frequencies of responses to the different questions are presented here in order that a primitive comparison can be made.

N.B. the wording of the questions differed slightly for public and school audiences. The term '*physics*' was used in the school questionnaires, for the public events this was replaced by the more generic term '*science*', reflecting differences in the content of the activities. Science festival visitors were asked to rate the festival on a five-point scale from '*very good*' to '*very bad*'; for the other interventions the five point scale was '*very interesting*' to '*very boring*'. Science festival visitors were not asked if the science at the festival was appropriately pitched; the festival comprised many activities and each would have needed to be considered separately.

Figure 8.12 Comparison of indirect measures of all activities' impact

	Year 8 Space Centre		Year 10 Science is Cool		AS & A2 Great Balls of Fire		AS & A2 Culham visit	Publics Science Festival		Publics Generic Venue
	Males %	*Females %*	*Males %*	*Females %*	*Males %*	*Females %*	*Males & Females %*	*Males %*	*Females %*	*Males & Females %*
Perceive positive attitude shift	31	38	13	15	13	18	10	44	41	62
Perceive 'some' physics/science learned	76	72	61	57	66	61	78	64	77	76
Rate activity as good/interesting	88	91	82	79	87	87	86	100	98	93
Scientific level of activity appropriate	84	74	79	88	75	83	77	n/a	n/a	90
Fun way to learn	77	76	n/a	n/a	n/a	n/a	n/a	99	99	100

NB some results are not separated according to gender because sample sizes were too small to allow meaningful interpretation of the results

It can be seen from these data that the impact of the activities aimed at publics appears to be stronger as measured by the indirect indicators. However, drawing a conclusion that these activities do indeed have a greater impact, some other factors should be taken into account. Firstly, the data collection methodologies differed between the schools and public interventions. Census sampling was impossible at the public events, so structured interviews were used instead of questionnaires to avoid self-selecting sample bias. This may mean that the results are more positive than in the questionnaire-based studies, as interviewees may feel obliged to give what they feel is the most desirable response. In addition, the sample size for the generic venue activity was considerably smaller than the other samples, with only 42 respondents. Secondly, different audiences may be more susceptible to attitudinal or cognitive shifts. Thirdly, as these results are based on self-reported data, the way in which individuals define their own learning and attitudes must be taken into account, and it is likely that these self-imposed definitions differ widely between audiences. Bearing these caveats in mind, the apparent trends in the results will now be discussed.

Especially interesting are the percentages of public respondents who felt their attitudes towards science had changed. This indirect indicator was found to relate to the direct measures for attitudinal shifts within the school students. If this indicator is indeed robust, the data suggest that the activities aimed at publics have a stronger affective impact than the schools activities. This is especially true for the '*inattentive*' publics targeted for the '*Science in the Fast Lane*' activity delivered in a generic venue. Audiences at the public events also rated their own learning as greater; however this indicator was found to be less robust than the self-perceived attitudinal shift.

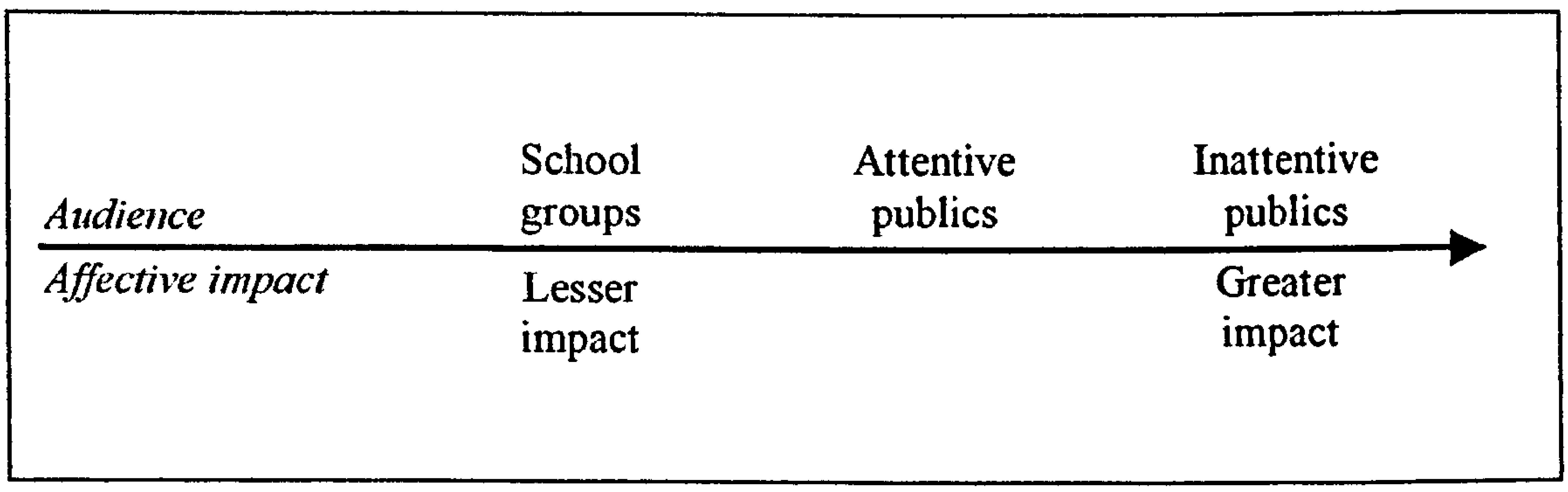
8.3.5 Comparison of activities along research axes

In the original design of this research, the activities were chosen to fit within a framework defined by two axes, as described in Chapter 1. The impacts of activities along each axis will now be considered and discussed. All of the activities evaluated were found to have cognitive impact. However, the measures of knowledge and learning were reasonably primitive. For these reasons, the present section of the discussion focuses on the affective impact of the activities evaluated.

Target audience

Figure 8.13 shows the association between the levels of affective impact (measured using the indirect indicators) and types of target audience for the interventions described in this thesis.

Figure 8.13 Target audience and affective impact



The trend within the activities evaluated appears to show that the activities aimed at publics had a greater affective impact than the activities aimed at school groups. Within the school groups' activities, the National Space Centre visit appeared to have the strongest affective impact on audiences. However, according to the indirect indicator for attitude shift, the impact was less great than the impacts on publics.

Within publics, the activity targeting 'inattentive' publics ('*Science in the Fast Lane'*, Chapter 7) had a greater affective impact than the activity attracting 'attentive' or 'interested' publics (Cheltenham Festival of Science, Chapter 6), as measured using the indirect indicators. This is understandable; many of the interviewees at Cheltenham Festival of Science said that the festival had not changed the way they felt about science because they had a pre-existing interest in the subject. Indeed, audiences had free choice as to whether they attended, and were unlikely to do so had they not been motivated by such an interest. The audiences at '*Science in the Fast Lane*', however, had minimal choice as to whether they attended (although only those who watched the show were interviewed). Many audience members were approached in the motorway service stations and presented with the science tricks or activity packs. For this reason, there were a larger proportion of respondents who did not have a pre-existing positive attitude towards science present than at the science festival. However, since the sample size for the generic venue study was considerably smaller than the other samples, it would be unwise to generalise from these results.

Venue

For the purposes of the current discussion, the axis describing activity venue will be presented in two parts, one for schools audiences and one for public audiences. Figure 8.13 indicates that impact is related to target audience, and as each activity had a different target audience any placement along an axis would be unreliable. Figure 8.14 shows the association between the levels of affective impact (measured using the direct and indirect indicators) and activity venue for the schools interventions described in this thesis.

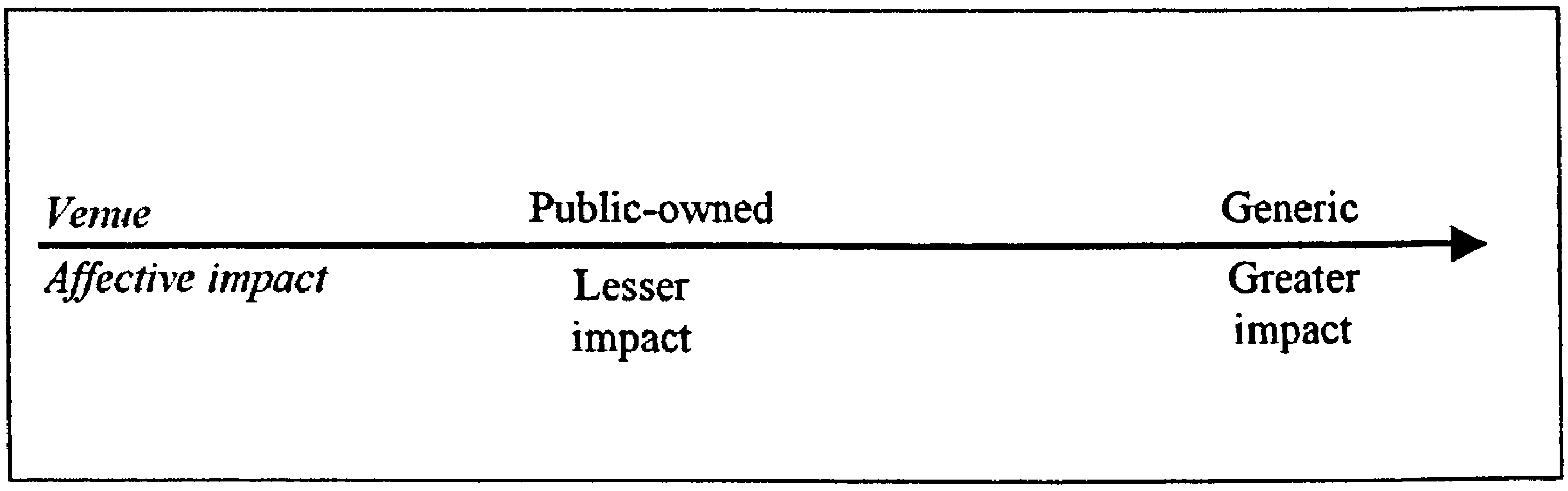
Figure 8.14 Activity venue and affective impact – school audiences

Venue	School	Museum or Science Centre →
Affective impact	Lesser impact	Greater impact

The trend within these data indicates that, for school students, interventions involving visits out of school have a greater impact than those delivered in school. This finding would be obvious to any science teacher; however there are many costs associated with organising school trips, both financially and in terms of time. Finding cover and obtaining consent from parents and guardians are also issues. In contrast, activities such as demonstration lectures are far easier to organise, although their affective impact would appear to be less great. However, the Challenger mission students undertook as part of the National Space Centre visit is a highly immersive experience where students are assigned roles and there is no choice over whether or not to engage. This means that there is no option for students attending the visit to 'opt-out'. Similarly, the planetarium show '*The Planets*' employs electronic voting throughout to encourage engagement from students. In contrast, a demonstration lecture, no matter how well designed, is rarely as immersive. It is easier for disinterested students to disengage with a lecture, especially if, for example, they are unable to see the presenter (as was the case for some students in Year 10). If a similarly immersive activity were provided in school, the differences in the affective impacts on students may not appear so marked as in the current research.

Figure 8.15 shows the association between the levels of affective impact (measured using the indirect indicators) and activity venue for the interventions aimed at publics described in this thesis.

***Figure 8.15** Activity venue and affective impact – public audiences*



The activity delivered in a generic venue appeared to have a greater impact on its audience than the activity delivered in public-owned venues. However, this is quite likely to be a result of the audiences targeted by the two activities, rather than a function of the venues themselves. The interaction between the two variables, audience and venue, makes comparing these interventions problematic.

8.4 DISCUSSION

8.4.1 Pre-existing attitudes towards physics

Year 10 students were less likely than Year 8 students to agree physics is an interesting subject, and reject the notion that it is boring. The perceived relevance of physics was also greater amongst Year 8 than Year 10 students. This apparent decline in attitude was more marked for females than for males. These data support the trend for declining attitudes towards the physical sciences described in Chapter 1. Despite this, a higher percentage of Year 10 males than Year 8 males claimed to like physics. Physics was, understandably, seen in a more positive light by AS- and A2-Level physics students. Few students from any of the respondent groups perceived physics as easy, and mathematical ability was seen as more important amongst the older students. AS- and

A2-Level students were significantly more likely to agree that physics is a boys' subject, possibly due to the male-dominated nature of this sample.

8.4.2 Comparison of schools activity impacts

As seen in Chapters 3, 4 and 5, and Figure 8.8, all of the schools activities had a significant cognitive impact on students, with the exception of Year 10 males. From the comparisons made in the current chapter, it appears that the visit to the National Space Centre, including the Challenger mission, had the greatest affective impact on students. A number of factors are likely to have contributed to this increased impact. A visit where students are taken to a new non-classroom environment is likely to provide greater interest than an activity held in a familiar venue such as a school hall. In addition, the programmes and exhibits at the National Space Centre are extensively researched to appeal to student audiences, and the simulated Challenger mission is a highly immersive environment. Space science is also an area of physics in which many students have an existing individual interest (Osborne, 2000). Combined, these factors are likely to have stimulated a high level of situational interest in students, reflected in their more positive responses to the attitudinal indicators following the visit. Another factor may be the age of the students involved. It has been noted that, at Key Stage 3, students' attitudes towards science are more malleable than at Key Stage 4, when they have solidified into attitudes that may stay with students for life (Williams *et al*, 2003; Spall, 2004; House of Commons, 2002). If this is the case, perhaps students in Year 8 are more receptive to interventions like the National Space Centre visit, meaning that such activities have a greater affective impact.

8.4.3 Comparison of all activities and future work

When compared along the research axes described in Chapter 1, it appears that the activities that targeted publics had a greater affective impact than those that targeted school groups. Within the activities aimed at publics trends do appear, but it is difficult to draw conclusions owing to the unclear influence of the different audience demographics and different sample sizes for the two activities targeting publics. Within the school groups, the activity delivered in a venue outside school had a greater impact than those delivered in school. The study in Chapter 5 (Culham) originally aimed to compare a schools-based intervention with a similar intervention held at a research facility, however only a small sample was obtained for the visits so the results were inconclusive. As suggested at the end of Chapter 5, repeating this study using more appropriate methods (for example unstructured or group interviews for students participating in the visits, and a longitudinal study design) would allow the impacts to be explored in a more useful manner. Future research would assist in clarifying some of the other issues raised in this thesis. For example, a study design that involved using a similar intervention (for example, the 'Science is Cool' demonstration lecture) but adapted for Year 8, Year 10 and AS- and A2-Level Physics students would allow the effect of audience age on activity impact be explored in greater depth. The differential impact on male and female students could also be investigated in such a study.

Another interesting area for future work would be in exploring the relationship between the direct and indirect indicators. A more powerful method than the one used in the current thesis would be to have a larger number of indirect indicators that generated ordinal data in the same form as the direct indicators. This would allow more powerful statistical tests to be performed, and correlations between indirect and direct indicators explored. Such research would be of great value to science communicators, who currently rely on relatively crude measures of impact for activities. In addition, funders are placing increased emphasis on measuring the impacts of activities. This is commendable, and indirect indicators that reliably link to true measures of cognitive, affective and behavioural change would assist practitioners in measuring such impacts.

Further development of the axes

It is difficult to use the existing axes in a meaningful way to compare the activities, since a number of factors (in addition to audience and venue contribute to the impact of an activity. At the outset of the research, it appeared that audience and venue were variables associated with activities that were independent enough to form useful axes. However, it now appears that this assumption was naïve, different venues will by their nature attract different audiences. For this reason, some of the variables identified as a result of the current analysis can now be used to form more robust axes in more than two dimensions. Examples of such variables include whether activity attendance is free choice, and the levels of maximum and minimum engagement with an activity. These variables are explored in greater detail in the next chapter, where they are used to form axes along which different science communication activities can be placed, providing a useful mapping tool.

Chapter 9

TOWARDS AN ALTERNATIVE FRAMEWORK FOR MAPPING SCIENCE COMMUNICATION ACTIVITIES

9.1 INTRODUCTION

This thesis has considered the impacts of five different science communication activities, aimed at different audiences and held in different venues. In order to make any form of comparison between the activities, they must be placed in a framework relative to one another. One appropriate framework consists of the two axes described in Chapter 1, corresponding to ***target audience*** and ***venue***. Limitations of these axes were discussed in Chapter 8. In addition, these axes would not necessarily be appropriate for many of the other science communication activities that take place in the UK. For this reason, it was decided explore axes that may be used to map a wider range of science communication activities. Mapping exercises have been conducted before, for example as part of the Wellcome Trust/OST study '*Science and the Public*' (2000), although the axes presented in this chapter reflect few of the same criteria, so could be considered a complementary approach to mapping activities.

Why map activities?

There are a number of potential benefits to science communicators of placing an activity on a particular axis or map. Firstly, the exercise of placing the activity on the relevant axes would assist in the clarification of the activity aims. Secondly, it would allow other activities in a similar genre to be identified, and good practice and learning from previous similar activities would assist in maximising the impact of the new activity. Thirdly, guidance on evaluation strategies for different types of activity already exists, for example RCUK/OST '*Evaluation: practical guidelines*' (2005), and accurate mapping may allow the most suitable evaluation strategy for the activity to be identified and implemented at an early stage in the project.

9.2 DIMENSIONS

The ranking exercise detailed in Appendix 9.1 was conducted with a colleague in the science communication field. This allowed discussion of the relative positions of the activities. A number of possible dimensions were considered in the context of 25 diverse science communication activities, including the ones evaluated in this thesis, some that one or both of the researchers had evaluated, and others chosen to provide as diverse a range of activities as possible.

The activities were assigned relative positions within each dimension by considering the relative positions of activities from the perspective of a member of the activity's target audience. The ***level of audience engagement*** dimension considered the maximum level to which an audience member could engage in an activity, and the minimum level of engagement that would be required to consider an individual to be engaged in the activity. The ***avoidance*** dimension described the ease with which a disinterested potential audience member could avoid an activity. Typical levels of audience engagement were considered within the ***intensity of experience*** dimension. ***Potential audience size*** and ***activity reach*** were also dimensions that were considered. In addition, ***topicality of scientific content*** and ***direction of knowledge/information transfer*** between specialists and non-specialists were included. It is important to note that the criterion for the selection of a dimension was that it must not judge the value of the activities within it. In other words, the positions are not an indication of one activity having a greater value than another; a scientifically literate society will be one that encourages a range of different science communication activities with a variety of aims and messages. A number of factors were found to contribute to the relative position of activities within each of the dimensions explored, and emerged as categories of activities within each dimension. For example, level of choice in attending an activity was found to be a factor affecting the position of activities within the ***avoidance*** dimension. These emergent factors were used to form axes, which, when combined, can produce a framework into which science communication activities can be placed.

It is important to note that each activity was considered from the perspective of a member of its target audience. Adopting this audience perspective allowed diverse activities aimed at different audiences to be compared within the same dimension, but also led to some limitations of the axes, as described in Section 9.3.2. The activities used in the exercise (including the activities evaluated in this thesis) and their relative positions within each dimension, are given in Appendix 9.1.

9.2.1 Engagement dimension

Maximum level of engagement

Within the engagement dimension, maximum and minimum levels of audience engagement were considered. Maximum level of engagement with an activity was defined as the experience of an individual who was offered (and took) every possible opportunity to engage with the activity. Whether the engagement was with scientific or issues-based material was not distinguished. Figure 9.1 shows the emergent categories and their associated activities.

Figure 9.1 Categories for maximum level of engagement in an activity

Category	Types of activity
Highest maximum level of engagement	
Activities where the content is decided by participants	Competitions involving entrants preparing material
Activities which allow engagement over a long period	Planet Science, sign-up email resources for teachers
Immersive activities involving prescribed roles	Role-play activities such as the Challenger learning centre
Dialogues and debates - more than one opportunity to engage	Science Festivals, dialogue activities such as the Royal Society dialogue programme, Science Cafés
Dialogues and debates - one-off opportunity to engage	Dialogues and debates, pub quizzes, consultations
Participatory activities	Science Discovery Centres
Activities that involve human interaction	Role model schemes, science busking activities
Presentations, small audience contribution	Demonstration lectures, live presentations
Interactions with media – some feedback mechanisms	Science publications (with feedback pages), poster schemes with text or other feedback
Interactions with media – no feedback mechanisms	Television/radio documentaries, poster campaigns, websites, computer games
Lowest maximum level of engagement	

The order in which the test activities were placed is given in Appendix 9.1 (page 280). There are a number of factors interacting to decide the position of an activity within this dimension. Firstly, it was assumed that activities where the content is decided by the participants would mean a high level of engagement, since time and effort are required to prepare the material for competitions such as CREST, where students present a scientific project, or FameLab, where entrants deliver prepared presentations. Activities such as school science fairs where students present a science project are another example of an activity in this category. Secondly, the amount of time over which engagement is possible was an important factor. Planet Science, which ran for a year, potentially offered a greater level of engagement than a science festival which runs over a few days or a week. Thirdly, the extent to which an activity is dialogical or discursive was important, and the inclusion of dialogue gave an activity a higher relative position. Participatory activities were defined as those which allow participation and one-on-one interaction between specialists and non-specialists, but not as a primary objective. The NOISE role model scheme, which involves media activities and presence at events such as science festivals, is an example of such an activity. Activities which involved live presentations of science, but where audience participation was limited (such as demonstration lectures) were positioned next on the scale. Finally, interactions with media were seen as having the lowest maximum level of engagement – those which allowed some level of feedback (such as the text response facility for poster campaigns such as SciBus or the letters page of New Scientist) were positioned above those which had no formal feedback mechanisms.

Because this scale considered maximum level of engagement, it does not take into account the handling of an individual's choice to engage. Factors contributing to this choice are: ways in which audiences are targeted or recruited, level of event facilitation and the activity venue. These factors were included in the next exercise, which considered minimum level of engagement.

Minimum level of engagement

Minimum level of engagement was defined as the minimum an individual could do and still be considered as engaged in the activity. It was important to consider this as well as the maximum level of engagement since for some activities the two levels of engagement are the same, while for other activities there is a marked difference in maximum and minimum engagement level. The categories identified and their descriptions are given in Figure 9.2.

Figure 9.2 Categories for minimum level of engagement in an activity

Category	Types of activity
Highest minimum level of engagement	
Activities where the content is decided by participants	Competitions involving entrants preparing material
Structured activities involving prescribed roles	Role-play activities such as the Challenger learning centre
Heavily facilitated discussions – zero-choice contribution	Structured dialogue activities, focus groups
Dialogues and debates – free choice contribution	Discursive or dialogue activities with some facilitation
Zero-choice presentations, interactives	Activities held in schools or where school groups are obliged to attend
Media – non-intrusive	Media that audiences would choose to engage with, e.g. Television documentaries, magazines
Media – intrusive	Media that audiences are presented with, e.g. in a generic venue, e.g. poster campaigns in schools or on buses
Lowest minimum level of engagement	

The order in which the test activities were placed is given in Appendix 9.1 (page 281). Choice became an important factor in the positioning of activities according to minimum level of engagement, and the nature of the choice to attend an activity and the choice to contribute to an activity were distinguished. Where attendance is '*free-choice*' the minimum level of engagement is higher than where it was '*zero-choice*', since making the effort to attend an event or use a form of media constitutes a greater level of engagement than where audience members have no choice in the matter. As with the previous scale, the competitions, where participants are in control of the content of the activity, had the highest level of minimum engagement. Directly following these were activities that are very structured or heavily facilitated, offering audience members no choice as to whether or not they can participate. In events where contributions are free-choice, the level of minimum engagement is lower as audiences can choose to 'opt out' of the discussion. Similar events held in generic venues or for school groups had a lower level of minimum engagement since these events are '*zero-choice attendance*'. Interactive activities were positioned lower as the audience is not considered captive, and media were positioned below these, as the effort to visit a Museum or Science Discovery Centre was deemed greater than the effort required to look at a poster or website. In the final two categories, media were distinguished as intrusive and non-intrusive. Non-intrusive media were defined as media where the choice to engage was made by the audience, for example by watching a documentary, or reading a book or magazine. Intrusive media, on the other hand, were '*zero choice*', and would include posters in schools or on buses.

The minimum level of engagement was assessed assuming that, for most of the activities, an audience member would still need to make the choice, for example, to attend an event, watch a television programme or look at a poster. This does not take into account how actively participants are recruited, or fully explore the implications of the type of venue in which an activity is delivered. For this reason, a further dimension was proposed to consider the extent to which an activity could be avoided by its target audience.

9.2.2 Avoidance dimension

Within this dimension, activities were ranked by the ease with which they could be avoided by members of the target audience/s who had heard about the activity; so the assumption was that the activities had been effectively marketed and promoted. The categories and their descriptions are given in Figure 9.3.

Figure 9.3 *Categories for potential avoidance of an activity*

Category	Types of activity
Most difficult to avoid	
Zero-choice attendance, zero-choice participation	Activities such as the Challenger learning centre
Zero-choice attendance	Events for school groups
Generic venue activities – live presentations	Activities held in generic venues such as pubs or supermarkets, science busking
Generic venue activities – media	Posters in schools or on buses
Free-choice attendance -active targeting of audiences through outreach or direct recruitment	Activities involving outreach e.g. Planet Science or Edinburgh Science Festival, or direct recruitment such as Cybertrust
Free-choice attendance - multimedia activities	Activities using more than one medium to communicate their message/s
Free choice attendance - single medium activities	Activities using a single medium (excluding live events)
Least difficult to avoid	

The order in which the test activities were placed is given in Appendix 9.1 (page 283). Zero-choice attendance activities were felt to be most difficult to avoid, and activities such as the Challenger experience at the National Space Centre, where participants are assigned a specific role, were placed at the top of the scale as participation is also zero-choice (although it is arguable whether this means the activity is more difficult to avoid). Activities in generic venues, where the audience do not choose to attend the science event, are also reasonably difficult to avoid, although engagement in the activity is at the discretion of each potential audience member. In this instance, activities involving live presentations and busking would be more difficult to avoid than posters or other media. Following these, activities where audience members have free choice over whether to attend were considered. Activities where efforts beyond 'standard' activity promotion were made to recruit audiences were deemed more difficult to avoid, for example in the case of Planet Science, where much outreach work was undertaken, or the Cybertrust dialogue, where members of the public were targeted and recruited in the cities where the meetings would take place, and paid for their contribution. The easiest activities to avoid were those that targeted audiences in traditional ways, or were media-based: where audiences must choose to visit a science festival, read a magazine or watch a documentary. It was felt that activities which employ a number of media, such as NOISE (which uses the web, role models, and broadcast and print media) are more difficult to avoid than those which are based primarily on one or two types of media.

Following the consideration of the three scales described above, a dimension of typical intensity of experience was explored.

9.2.3 Intensity dimension

This dimension aimed to explore the intensity of experience of a typical audience member for each of the activities. It was assumed that intensity of experience would be related to the impact of the activity. However a dimension for activity impact was not constructed in the current exercise as it was felt that such a scale would constitute something of a value judgement of the activities under consideration. The current scale combined the considerations of the previous scales regarding engagement and avoidance. The categories and types of activities are given in Figure 9.4.

Figure 9.4 *Categories for typical intensity of experience*

Category	Types of activity
Most intense experience	
Zero choice, expected contribution	Activities with audience-driven content, heavily facilitated dialogues, role-play activities
Discursive or one-on-one interactions, free choice contribution	Activities with more than one opportunity to engage, e.g. science festivals School activities involving visits, science cafés Facilitated, participatory activities held in schools Role model schemes
Presentations, low-level interaction, contribution not expected	Science busking, demonstration lectures
Media – free choice contribution (low level)	Magazines with letters pages, poster campaigns with text feedback
Media – zero-choice non-contribution	Books, television documentaries, computer games, websites
Least intense experience	

The order in which the test activities were placed is given in Appendix 9.1 (page 283). Since this scale is a product of the three previous scales, it displays features of each. The idea of choice is again important in the relative positions of activities. Zero-choice contribution activities are placed higher than those for which audience contribution is a free choice. Low level contribution activities are placed below discursive or dialogue activities on the scale. This ranking could be considered arguable; a book or television documentary that strikes a chord with its reader or viewer lead to a greater intensity of experience for that individual than attendance at an informal discussion event. This is not disputed; however, it would not be considered a 'typical' response in this context. Indeed, it has been assumed that interaction with other people or live presentation of science by a person would lead to a greater intensity of experience for an audience member. For this reason, and because media-based activities often offer no opportunity for audiences to contribute or shape their content, these activities are at the lower end of the scale for intensity of experience. Of course, the intensity of experience would depend on the amount of time for which an individual was immersed in the medium. It is interesting, yet unsurprising, to note that the activities near the top of the scale with the highest intensity of experience are those which require more resources per audience member. This leads to the idea of potential audience size and activity reach, which are discussed as the next two dimensions.

9.2.4 Audience size and activity reach dimensions

It was apparent while positioning activities along the scales relating to the previous dimensions that the reach and potential audience size of an activity were important factors. For this reason, activities were placed on scales relating to these criteria.

Potential audience size

Activities were positioned according to potential audience size. The descriptions of the categories are given in Figure 9.5.

Figure 9.5 Categories for potential audience sizes

Category	Example activities
Largest potential audience size	
Print and broadcast media	Documentaries, books, magazines, posters
Online media	Websites, online games
Ongoing accessibility, single location	Science discovery centres
Live presentations – ongoing but sporadic	Demonstration lectures
Live events – extended time/several locations	Science festivals, science cafés
Live events – time-limited	Consultations and dialogue collaborations, e.g. GM Nation
Specific target audience	Resources for teachers
Short-term projects and activities that require a high level of involvement	Competitions such as CREST, activities in pubs or supermarkets, discursive activities
One-off or specialist activities	Discursive activities, dialogues such as Cybertrust
Smallest potential audience size	

The order in which the test activities were placed is given in Appendix 9.1 (page 284). Media-based activities were considered to have the largest potential target audience, with print and broadcast media ranking higher than online media. Science centres were ranked next, as they are accessible throughout the year. Below these came live events and activities, with the timescale over which an activity takes place determining its position on the scale. Below this, the nature of an activity's target audience becomes an important factor. Activities with a specific target audience, for example resources aimed at teachers, are naturally going to reach a smaller number of people than those open to, say, the general public. Finally, activities that require a high level of engagement, or have audience-driven content, and one-off activities were placed at the end of the scale, representing smallest potential audience size.

Activity reach

Activity reach was defined as the geographical area over which the activities were accessible to their target audiences. Figure 9.6 shows the emergent categories.

Figure 9.6 Categories for audience reach

Category	Types of activity
Greatest reach - international	
International activities	European poster campaign
National media-based activities	National poster campaigns, websites, national magazines, television programmes
National – live activities	Lecture tours, science cafés, national consultations and dialogues
Regional – live activities, more than one venue	Regional discussion event and lecture tours, generic venue activities
Regional – live activities, single venue	Science centres, visits to research facilities
Least reach - regional/local	

The order in which the test activities were placed is given in Appendix 9.1 (page 284). Positioning the activities within this dimension was reasonably straightforward. Activities such as the European poster campaign were classed as international, and these were followed with UK-based media activities and websites. Although international audiences can engage with these activities, their target audience(s) are from the UK. Live activities were ranked as having a more limited reach, and the number and location of the venues of these activities became an important factor in their positions on the scale. Programmes where events take place in venues all over the country were ranked above those whose venues are distributed over a smaller region, and one-off activities were ranked below those. Science centres were ranked as having regional reach, although this is arguable depending on the nature of the centre; they can draw audiences from all over the UK. It was felt, however, that their reach is less because the onus is on the audience to travel the greater distance.

9.2.5 Direction of knowledge transfer

The next dimension considers the direction(s) in which knowledge is transferred between specialists (scientists, science communicators, policymakers etc) and non-specialists (publics). Specialists were defined as those with specialist knowledge on the scientific or other content of the activity, and non-specialists were those who were not in possession of this information. The positions of the activities is given in Figure 9.7.

Figure 9.7 Categories for direction of knowledge transfer

Direction of knowledge transfer	Types of activity
Specialist to non-specialist	Didactic activity. No mechanism for feedback e.g. demonstration lecture, website
	Didactic activity. Feedback collected from non-specialists – no means of dissemination to specialists
	Didactic/discursive activity. Some specialists present so feedback possible but unlikely
Two-way/multiway	Discursive/audience-driven activity. Specialists present, feedback mechanism not understood
	Discursive activity. Formal mechanism for non-specialist feedback
Non-specialist to specialist	Non-discursive activity. Information collected from non-specialists e.g. opinion poll

The activities and their positions are given in Appendix 9.1 (page 285). During the exercise, the nature of the material being communicated was not considered, so activities where the content involved science facts or careers were placed alongside those considering ethics. The categories on this scale appear to run from didactic activities (specialist to non-specialist) through discursive activities (two-way/multiway knowledge transfer) to consultations and opinion polls (non-specialist to specialist). Another scale appears to run parallel to the nature of the activities; the way in which feedback is structured. Where the information moves solely from specialists to non-specialists, there is no facility for non-specialists to feed back their views. These activities could be considered as following the deficit model for science communication. (Gregory & Miller, 1998) At the other end of the scale, where knowledge is transferred solely from non-specialists to specialists, there is often a formal information channel in place, such as the publication of a report following an opinion poll or consultation. In the centre of the scale, where the knowledge its transferred in two or more directions, the feedback mechanisms become less formal. Some activities, such as Small Talk, aim to explore ways of ensuring that the feedback process is effective, and with more work in this area the scale on this axis is likely to evolve over time. Also, as the emphasis for funders continues to shift from didactic to discursive or dialogical activities, it is likely that there will be a greater number of activities occupying the central area of the scale.

9.2.6 Topicality dimension

The next axis aimed to consider the scientific or issues-based content of activities, which was largely disregarded in the construction of the previous scales. Which scientific issues are topical at a given time is of course subject to change, so the relative positions in this case are at best a snapshot of 'hot topics' for early 2005. Descriptions of the categories are given in Figure 9.8.

Figure 9.8 Categories for topicality of scientific content

Category	Example topics
Upstream topics	
Will be a need for debate. Little regulation framework	Fusion power
Growing need for debate. Topics already identified through horizon scanning	Information security, nanotechnologies
Present need for debate. Regulation framework under development	Genetic screening, GM crops
Little need for debate perceived. Existing regulation framework	Space science, thermodynamics, robotics
Downstream topics	

The order in which the test activities were placed is given in Appendix 9.1 (page 285). Some of the emergent factors on this scale echo the scale proposed in '*Dialogue with the Public*' (RCUK/OST, 2002). This scale classifies activities into four groups according to their topicality. The groups are described in Figure 9.9

Figure 9.9 RCUK/OST (2002) controversy/public domain scale

1. Issues that are currently causing public controversy
2. Issues with a clear potential to cause public controversy
3. Issues where the impact on society is not yet established
4. Issues that are interesting but not controversial

The main difference between the scales shown in Figures 9.8 and 9.9 are the directions of the scales. The scale in Figure 9.8 uses the term 'upstream' to describe topics where the impact on society is not yet established and 'downstream' for issues that are interesting but not contentious (RCUK/OST, 2002; DEMOS, 2004).

Downstream topics typically have a well-developed regulation framework Figure 9.8 places upstream and downstream topics at either end of the scale, with 'hot topics' in the centre. The RCUK/OST scale places the most topical issues at the upper end of the scale, and the least topical at the lower end. Both are potentially useful ways of considering scientific issues.

There are a number of factors combining to give the activities their places within the dimension described in Figure 9.8, which is basically a measure of topicality and as such is itself open to much discussion. Topics where there is a present need for debate can be those that are generating the most media column inches and are high on the agendas of policymakers. They can also be the most contentious issues, possibly for political and economic reasons as well as scientific ones. Of course, what constitutes a 'hot topic' can change rapidly over time, a single headline can catapult a previously non-contentious topic into the spotlight, and there may be a sudden need for debate. Following the publication of the recent DEMOS report, '*See-through science*' (Wilsdon & Willis, 2004), the trend has been to move the debate upstream, to scientific topics identified through horizon scanning, and beyond. However, it is not necessarily only the upstream topics that may suddenly become contentious, new applications of 'downstream' science may lead to a call for new legislation. Robotics is an example of such a topic. For this reason, horizon scanning should take place both upstream and downstream of topics currently under scrutiny.

9.2.7 From dimensions to axes

The construction of the dimensions allowed interesting comparisons to be made between the activities, their audiences and the science they included. The emergent factors from each dimension were then combined to form independent categorical axes. These axes are presented in Figures 9.10 and 9.11.

Figure 9.10 Summary of emergent axes – engagement, avoidance and intensity dimensions; audience size and reach dimensions

High maximum and minimum levels of engagement, difficult to avoid, intense experience				Greatest reach
Audience contribution	*Level of audience ownership*	*Activity description*	*Intensity / audience size*	*Activity reach*
Zero-choice contribution	Audience-driven content	Zero-choice attendance		International
Structured/facilitated	Discursive or dialogical		Smaller potential audience size	
Free choice contribution	One-on-one interactions	Generic venue	Greater intensity of experience	National
	Live presentations	Active audience recruitment or outreach		
		Free choice attendance	Lesser intensity of experience	Regional
Contribution not expected	Media with feedback mechanism	Multimedia	Larger potential audience size	
Zero-choice non-contribution	Media with no feedback mechanism	Single medium		Local
Low maximum and minimum levels of engagement, easy to avoid, less intense experience				**Least reach**

Figure 9.11 Summary of emergent axes – direction of knowledge transfer and topicality dimensions

Knowledge transfer specialist to non-specialist		**Upstream topics**		
Feedback mechanism	*Nature of activity*	*Contentiousness**	*Need for debate*	*Regulation framework*
None	Didactic	Issues where impact on society not understood	Will be a need for debate	Little regulation framework
Feedback collected but not disseminated		Issues with clear potential to cause public controversy	Growing need for debate	Topics identified through horizon scanning
Feedback mechanism not understood				
	Discursive/dialogical	Issues that are currently causing public controversy	Present need for debate	Regulation framework under development
Formal mechanism for feedback from non-specialists to specialists				
Information channel	Opinion poll	Uncontroversial issues	Little need for debate	Existing regulation framework
Knowledge transfer non-specialist to specialist		**Downstream topics**		

* *Adapted from RCUK/OST (2002)*

The axes described in Figure 9.10 consider the activities from the perspective of an audience member. The nature of the audience is particularly important for the '*activity description*' scale, which was compiled from the perspective of an individual who is generally engaged in society, but without a particular interest in science. Such an individual is likely to engage with an activity if approached or encouraged, but would not necessarily do so under his or her own initiative.

9.3 DISCUSSION

9.3.1 Application of axes

The framework proposed in this chapter is intended as a starting point for future research in this area, rather than a conclusion. Creating a framework from axes that do not judge the value of the activities positioned along them should enable activities to be objectively described and compared.

Following the publication of '*Science and Society*' (House of Lords, 2000) and its call for a new mood of dialogue, the British Association for the Advancement of Science (the BA) were commissioned to recommend a process for government to support the communication between scientists, publics and policymakers (BA, 2002). Eleven recommendations were made, including:

> *"A detailed and ongoing mapping of science and society activities is provided through an actively managed database, in order to provide high quality, comprehensive and up to date information to the OST and other organisations, and potentially capable of development as a UK-wide information service for the public"*

> *"A range of* [Science Communication] *activities is evaluated, linked to the survey of the public, exploring which activities are most engaging for particular groups of people. This might include evaluation of the*

relative awareness and impact of many small activities to larger national or regional events"

The axes proposed within the current chapter provide an alternative framework in which to map activities, thereby allowing the relative strengths and weaknesses of activities which engage different audiences to be compared. Identifying the position of an activity within the framework will allow greater clarification of its aims and objectives, and will facilitate the selection and implementation of an appropriate evaluation strategy, especially if combined with other resources such as the RCUK/OST publication, '*Evaluation: practical guidelines*' (2005). In this way, information on the impact of different activities can be accumulated, and maps of impacts constructed alongside the maps of activities. This will allow areas of overlap and gaps in provision to be identified by the science communication community.

9.3.2 Limitations of axes

The axes have been constructed from the perspectives of the target audiences for different activities. This leads to several limitations. Firstly, it raises the question as to whether greater value should be placed on an activity that includes audiences who are described as 'hard-to-reach', for example some minority ethnic groups, or socially excluded groups, as opposed to 'attentive' or 'interested' publics. This is an important issue, and the fact that greater effort is required to promote inclusion is not fully accounted for within the axes. Secondly, placement of an activity on some axes becomes difficult as the activity becomes more complex. Cheltenham Festival of Science, for example, has a range of target audiences and includes a large number of different science topics. This makes it difficult to locate an exact position on some scales. For activities such as Planet Science, which was more complex again, the task becomes more difficult still. One way of addressing this problem would be to consider the smaller activities within, for example, a science festival, individually, and use the axes to compose a representation of the festival itself.

9.3.3 Further work

The axes in this chapter have been proposed, but not tested. In order to explore the robustness of the different axes, a useful exercise would be to collect information and evaluation data (where available) for each of the 25 activities used to construct the axes, and map them. It is likely that some axes would be found to be more useful than others, and perhaps that different activities would need to be mapped using different axes, corresponding to the aims and objectives of each activity. Following the mapping exercise, the maps produced could be compared with the resources on evaluation mentioned, and proposed evaluation methods for different positions on the axes compared. Another obvious extension of the work would be to repeat the exercise detailed in this chapter with a different set of activities, to examine whether the same factors emerged. This may allow the identification of further factors that should be included in a mapping framework of this nature, and would highlight areas of potential uncertainty. By providing a robust framework which allows science communication activities to be objectively mapped, individual evaluations can become more meaningful, ultimately leading towards a comparison between different activities and their impacts.

9.4 CONCLUSIONS

Activities and their impacts

Each activity evaluated in the thesis was found to have an impact on the cognitive (knowledge and understanding) and affective (feelings and attitudes) domains of members of its target audience. The day-long visit to a science centre appeared to have a greater impact than those activities delivered over a shorter time period in schools, although the immersive nature of the visit was also likely to have contributed to the impacts measured. The demonstration lectures appeared to have a lesser affective impact. It was unclear how the age or pre-existing attitudes of audiences would affect their potential attitude or knowledge shifts; it could be that younger students are more likely to experience stronger changes in attitude than older students. For public audiences, the activity aimed at 'inattentive' publics appeared to have a positive impact on cognition and affect. The affective impact of the science festival appeared less great, however the audience demographics for the activities were very different, and it was impossible to separate the influences of audience and activity type. The science festival was also found to have a sustained impact, and an impact on some visitors' behaviours.

Axes and mapping

The axes used to map the activities at the inception of the project, activity venue and activity target audience, were found to have certain limitations. Through the consideration of these limitations, the construction of a more robust mapping framework was possible, and the alternative axes developed in this thesis can be used to consider a wider range of activities. Although not without its limitations, such a framework has great potential value for science communication practitioners.

Appendix 9.1

- Results of ranking exercise

Activities included in the exercise

Activity name	Provider	Funder	Brief description
Planet Science	NESTA / British Association / Association for Science Education	DfES	The follow-up to Science Year, Planet Science comprises a website and suite of activities aimed at every school student in England and Wales, delivered by targeting their teachers
GM Nation			A nationwide consultation conducted by government with publics regarding genetically modified organisms
Cheltenham Festival of Science	Cheltenham Festivals	Several	A 5 day science festival comprising talks, debates and interactives
CREST	British Association	Supported by various sponsors	A competition aimed at KS4 school students who have to present a science project to panels of judges in local, regional and national heats
Cybertrust	Royal Society	Royal Society	Part of the Royal Society's dialogue programme, a series of events exploring the views of publics on Cybertrust and information security to inform future policy
Small Talk	BA / RI / Cheltenham Festival of Science/ ECSITE – UK	COPUS grant scheme	A collaboration between a number of science communication providers to co-ordinate dialogue events on nanotechnologies with a view to influencing policy
Meet the Mighty Gene Machine – schools	Graphic Science	The Wellcome Trust	A drama and facilitated discussion for school students designed to stimulate debate over the application of genetic screening – held in schools
Meet the Mighty Gene Machine – Science centres	Graphic Science	The Wellcome Trust	A drama and facilitated discussion for school students designed to stimulate debate over the application of genetic screening – held in science centres
FameLab	Cheltenham Festival of Science	NESTA	A competition to find new talent in science communication, loosely based on a reality TV format
Space Centre visit, including Challenger Centre	National Space Centre	National Space Centre	A visit to the Space Centre including the planetarium show 'The Planets' and the Challenger learning experience
Café Scientifique	Local	Local	Informal presentation and discussion in a café, restaurant or bar venue

Activity name	Provider	Funder	Brief description
UpD8	Sheffield Hallam University		An email update service for science teachers that describes the science behind current news stories for incorporation into lessons
Techniquest			A science discovery centre based in Cardiff
NOISE	Momenta	EPSRC	A role model scheme which uses a website, presence in the broadcast and print media and direct engagement at events such as science festivals to promote science careers to young people
'*Great Balls of Fire*' fusion lecture– in school	Culham Science Centre	Culham Science Centre	A lecture about nuclear fusion aimed at AS and A2 Level physics students, held in school
'*Great Balls of Fire*' fusion lecture – at facility	Culham Science Centre	Culham Science Centre	A lecture about nuclear fusion aimed at AS and A2 Level physics students, held at Culham Science Centre and combined with a tour of the research facility
Planet Arkive	Wildscreen	Several	An online catalogue of endangered species
New Scientist			Popular science magazine
Pub Genius	Graphic Science	COPUS grant scheme	Science-based pub quiz incorporating science demonstrations using objects often found in pubs
Science in the Fast Lane	Graphic Science	COPUS grant scheme/IoP	Science busking at motorway service stations, activity packs were also distributed to children to help alleviate boredom during car journeys
'Science is Cool'	University of Liverpool		A liquid nitrogen demonstration lecture aimed at Year 10 audiences and held in school
Time Twins		Institute of Physics	A simple online game involving time travel
Einstein's Brain	Channel 4		A documentary exploring Einstein's physics and the neurology of genius
SciBus	Graphic Science	European Commission	A poster campaign on buses throughout Europe where audiences could give their opinion on the questions posed by SMS
Dirac Posters	Graphic Science	Institute of Physics	Posters about the work of Paul Dirac for display in schools

Each activity was written on a flashcard, and the cards were used to place each activity within one of the dimensions under consideration, considering the activity from the perspective of an audience member.

Maximum level of engagement

Category	Activity
Highest maximum level of involvement	
1	FameLab / CREST
2	Planet Science / UpD8
3	Space Centre and Challenger visit
4	Cheltenham / Cybertrust / Small Talk / Café Scientifique GM Nation / Gene Machine (school) / Gene Machine (science centre) / Pub Genius
5	Techniquest
6	NOISE / Science in the Fast Lane
7	Fusion lecture (at facility) Fusion lecture (school) / Science is Cool
8	SciBus / New Scientist
9	Time Twins / Planet Arkive Einstein's Brain Dirac Posters
Lowest maximum level of involvement	

Minimum level of engagement

Category	Activity
	Highest minimum level of involvement
1	CREST / FameLab
2	Space Centre and Challenger visit
3	Cybertrust
4	GM Nation Café Scientifique / Cheltenham / Small Talk
5	Gene Machine (science centre) / Gene Machine (school) / Science is Cool / Science in the Fast Lane / Fusion lecture (school) / Fusion lecture (facility) / Pub Genius Time Twins / Techniquest
6	Einstein's Brain
7	NOISE / Planet Arkive / Planet Science / UpD8 / New Scientist
8	Dirac posters / SciBus
	Lowest minimum level of involvement

Potential avoidance by target audience

Category	Activity
	Most difficult to avoid
1	Space Centre and Challenger visit
2	Fusion lecture (school) / Fusion lecture (facility) / Techniquest (schools) / Gene Machine (school) / Gene Machine (science centre) / Science is Cool
3	Science in the Fast Lane / Pub Genius Dirac posters / SciBus
4	Planet Science Cybertrust / CREST
5	NOISE New Scientist
6	UpD8 / Time Twins / Planet Arkive / Einstein's Brain / Cheltenham / GM Nation FameLab / Café Scientifique / Small Talk / Techniquest (publics)
	Least difficult to avoid

Intensity of experience

Category	Activity
	Typical experience most intense
1	Cybertrust FameLab / CREST Space Centre and Challenger visit
2	Techniquest / Cheltenham / GM Nation / Small Talk Pub Genius / Café Scientifique / Gene Machine (science centre) / Fusion lecture (facility) Gene Machine (school) NOISE
3	Science in the Fast Lane / Science is Cool / Fusion lecture (school)
4	New Scientist / SciBus
5	Einstein's Brain / Time Twins Dirac posters / Planet Arkive
	Typical experience least intense

Planet Science and UpD8 were not included in this dimension – it was felt that the level of involvement in these different aspects of these activities varied so widely it was difficult to define 'typical' involvement. These activities occupied opposite ends of the maximum and minimum level of engagement scales.

Activity reach and audience size

Category	Activity
	Largest potential target audience
1	Einstein's Brain / SciBus / Dirac posters / New Scientist / Planet Science
2	Planet Arkive / NOISE / Time Twins
3	Techniquest / Space Centre and Challenger
4	Science is Cool / Fusion lecture (school)
5	Cheltenham / Café Scientifique
6	Small Talk / GM Nation
7	UpD8
8	CREST / FameLab / Science in the Fast Lane / Gene Machine (school) / Gene Machine (science centre) / Pub Genius
9	Cybertrust / Fusion lecture (facility)
	Smallest potential target audience

Category	Activity
	Greatest reach - international
1	SciBus
2	NOISE / Planet Science / Planet Arkive / New Scientist / Dirac posters / Time Twins / Einstein's Brain / UpD8
3	Small Talk / Cybertrust / Fusion lecture (school) / Science is Cool / GM Nation / Café Scientifique / CREST / FameLab
4	Science in the Fast Lane / Gene Machine (science centre) / Pub Genius / Gene Machine (school)
5	Techniquest / Space Centre and Challenger visit / Fusion lecture (facility)
	Least reach – regional/local

Direction of knowledge transfer

Direction of knowledge transfer	Activity
Specialist to non-specialist	Planet Science / UpD8 / Dirac posters / Time Twins / Space Centre and Challenger visit / Einstein's brain / Techniquest / Pub Genius / Science in the Fast Lane
	Planet Arkive / CREST
	Fusion lecture (school) / Fusion lecture (facility) / Science is Cool / NOISE / Gene Machine (school) / Gene Machine (science centre) / New Scientist
2-way/multiway	FameLab / Cheltenham / Café Scientifique / Small Talk
	Cybertrust / GM Nation
Non-specialist to specialist	MORI opinion poll*

*activity was added to the list for the purpose of this ranking exercise. It illustrates a one-way non-specialist to specialist knowledge transfer.

Scientific content of activities

Category	Activity	
	Upstream topics	
1	Fusion lecture (school) / Fusion lecture (facility)	Café Scientifique / Cheltenham
2	SciBus / Cybertrust / Small Talk / UpD8	
3	Gene Machine (school) / Gene Machine (science centre) / New Scientist / GM Nation	
4	Einstein's Brain / Planet Arkive / Planet Science / CREST / Techniquest / Space Centre and Challenger visit / Science in the Fast Lane / NOISE / Pub Genius / Science is Cool / FameLab / Dirac posters / Time Twins	
	Downstream topics	

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