

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

<i>Percentage of the public</i>	<i>Main attitudinal characteristics</i>	<i>Demographic profile</i>
20%	<i>Technophiles</i> – 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%	<i>Confident Believers</i> – 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%	<i>Supporters</i> – 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%	<i>Not Sure</i> – 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%	<i>Not for Me</i> – 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%	<i>Concerned</i> – 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

<i>Value set</i>	<i>Demographic profile</i>
<i>Green values</i> – interested in the environment and ethical issues associated with animal experimentation. Concerned with the pace of science and interfering with nature	Girls
<i>Techno-investor</i> – reflected a generally buoyant attitude to scientific development. Supported technological investment. Trusted the government and scientists	Boys and young men
<i>Science-oriented</i> – reflected a general interest in science and technology topics and endorsed a ‘ <i>scientific way of thinking</i> ’	Young men
<i>Alienated from science</i> – 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' (Laugksii, 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).

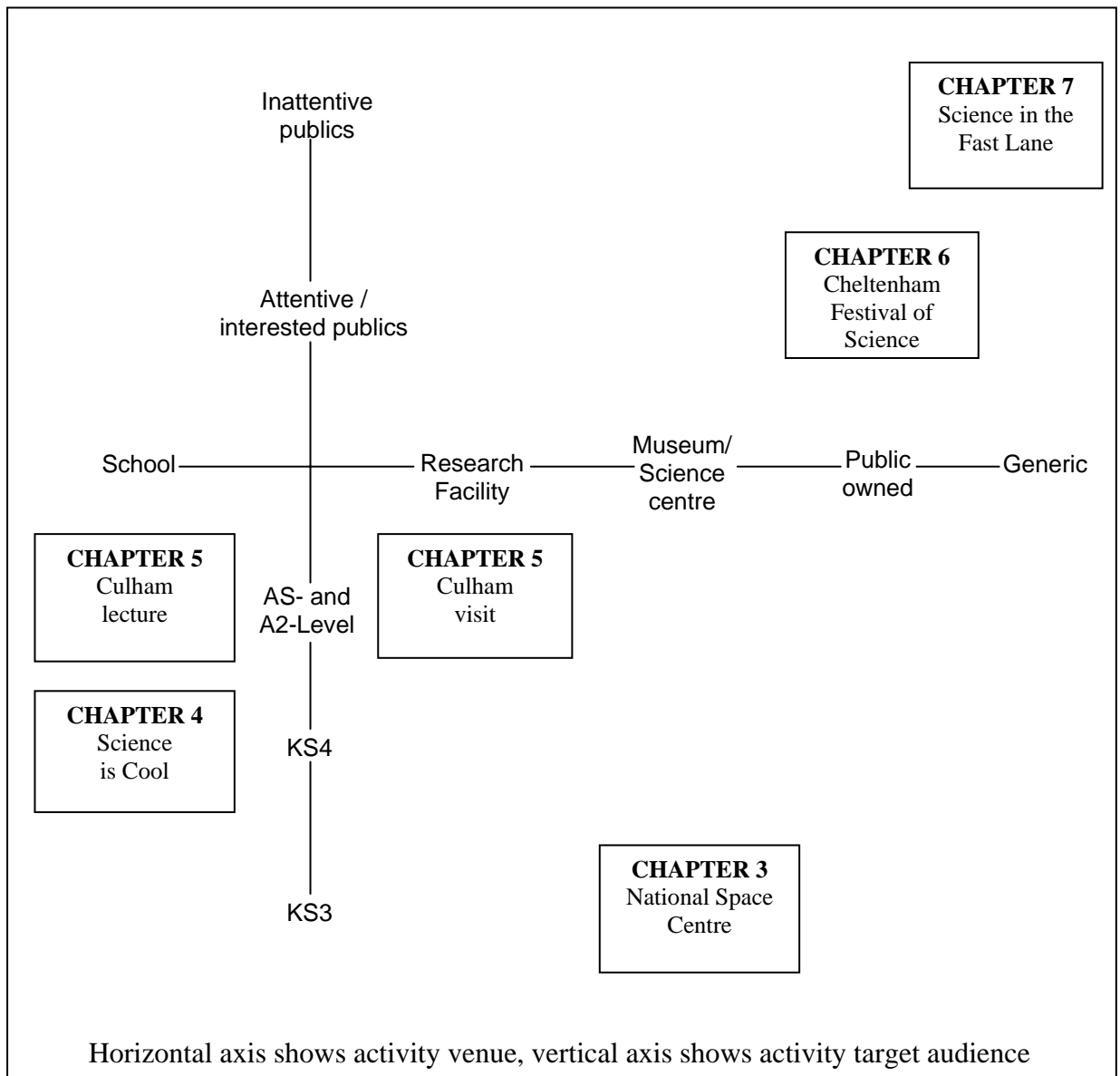
1.5 FOCUS OF THE CURRENT RESEARCH

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



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.

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 ' <i>The Planets</i> ' 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.