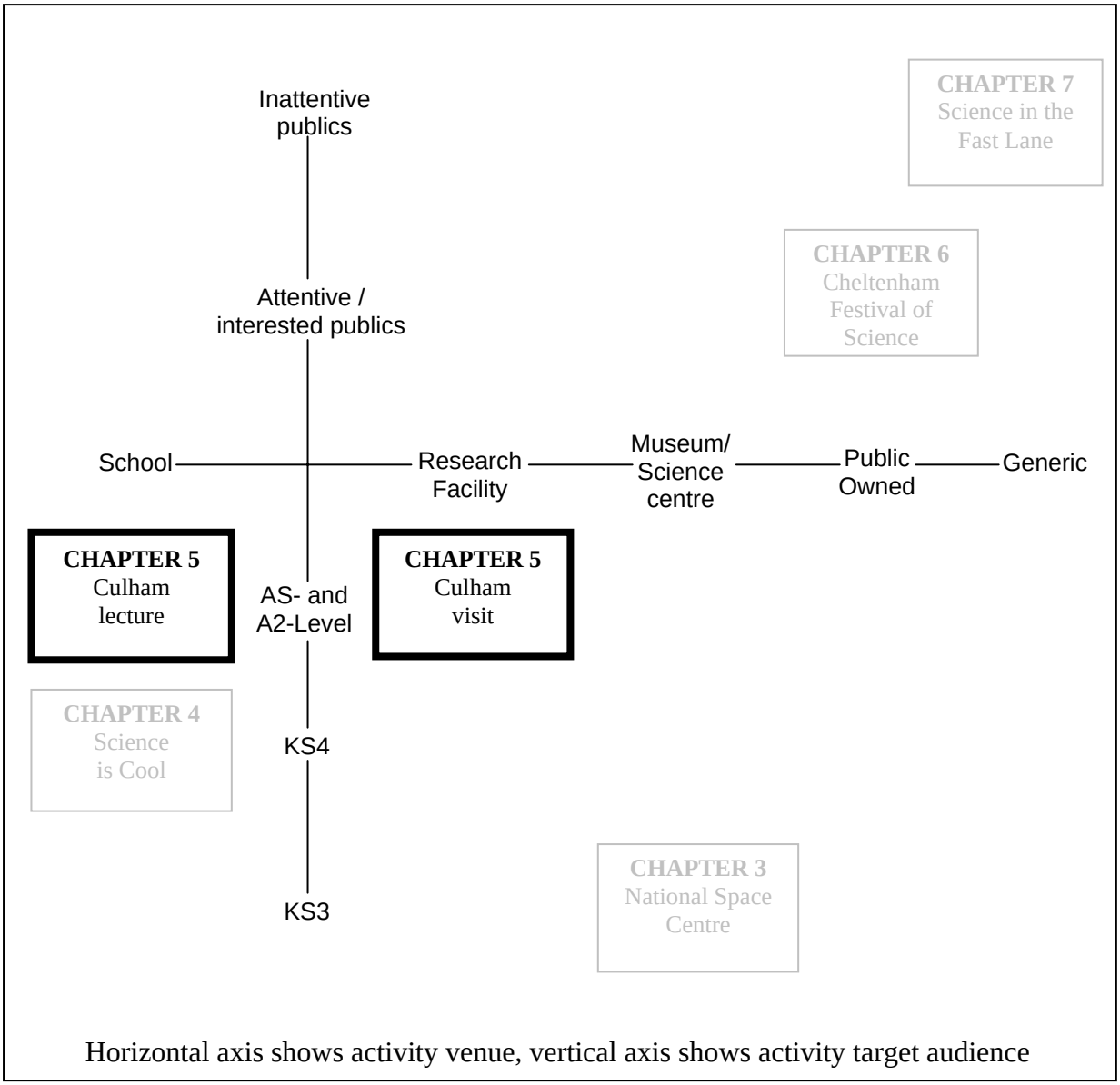
Chapter 5

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

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

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

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