Chapter 8

META ANALYSIS

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.

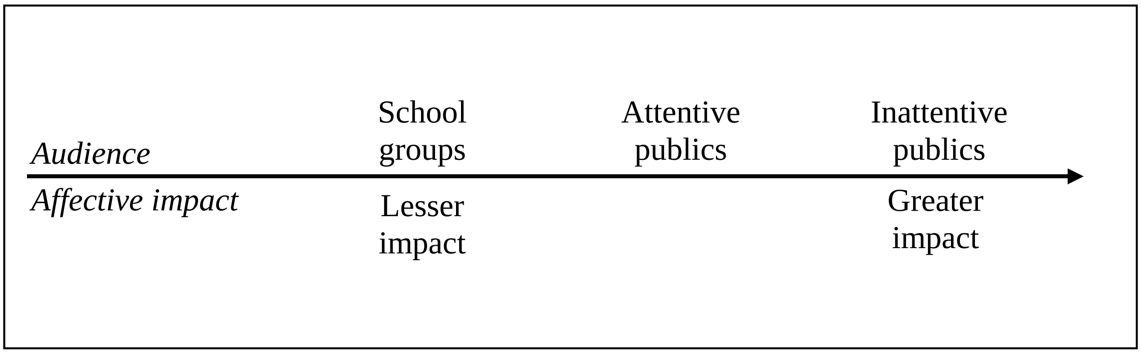
8.3.5 Comparison of activities along research axes

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.

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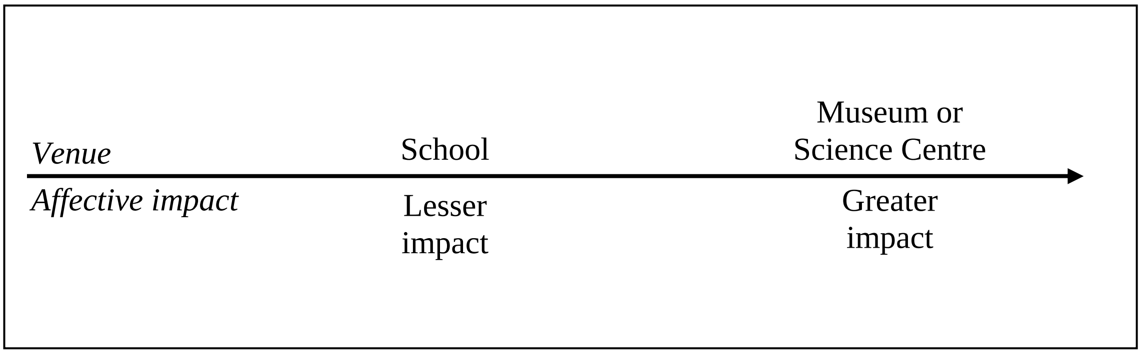
Venue

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.

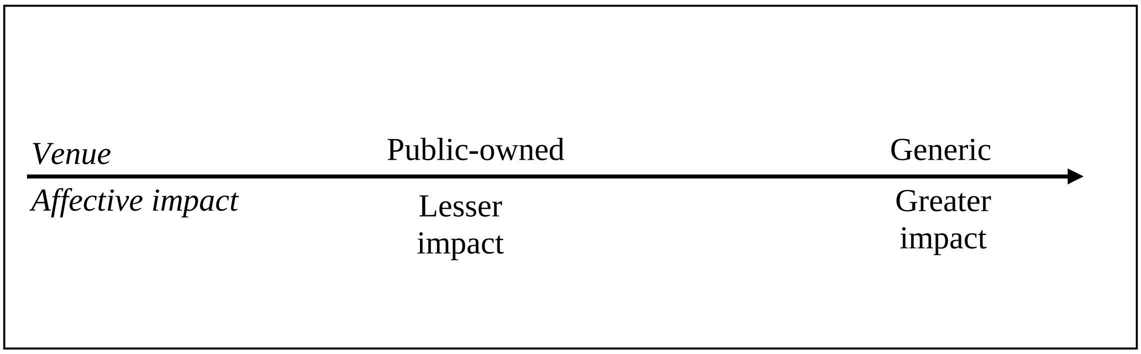
Figure 8.14 *Activity venue and affective impact – school audiences*



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. 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.

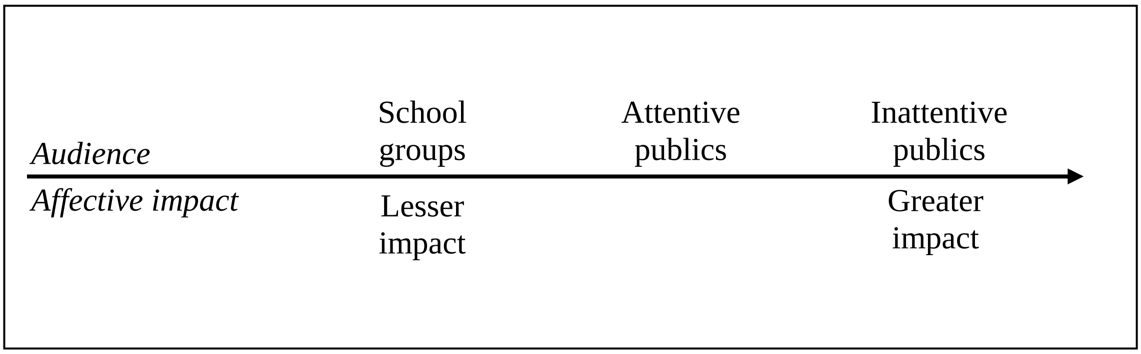
8.3.5 Comparison of activities along research axes

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*



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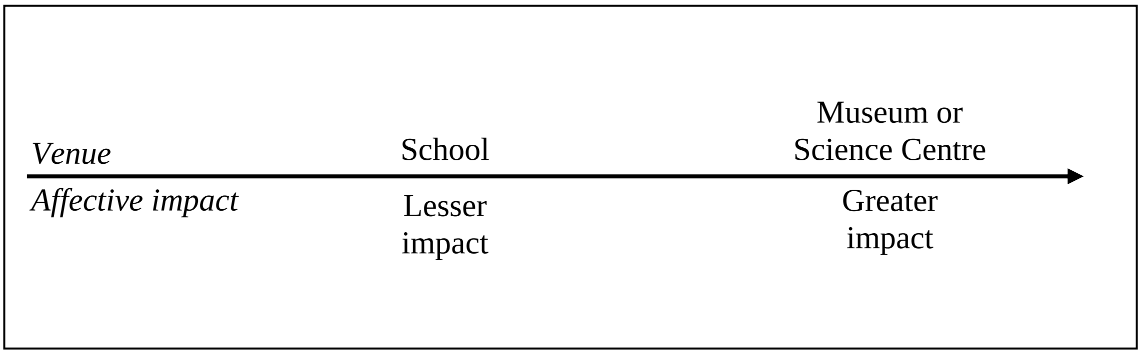

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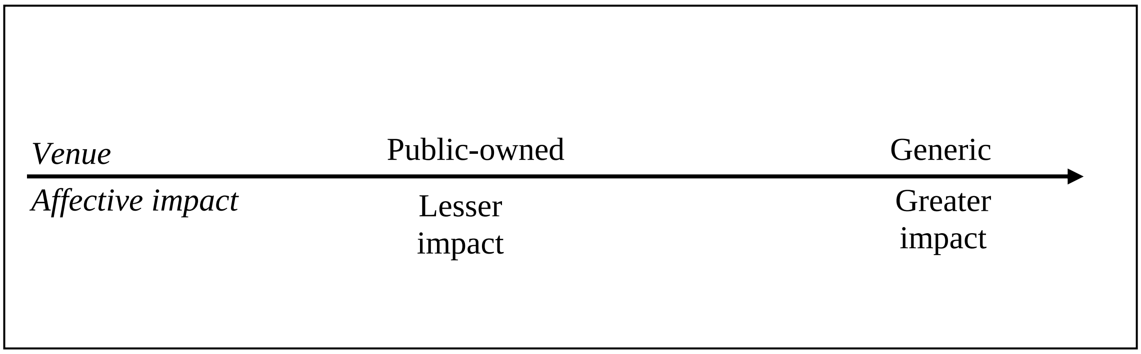

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