Gravity Beyond the Apple

Evaluation Report

Prepared for:

Science Made Simple

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Contents

1 Introduction

Gravity Beyond the Apple is a partnership between the School of Physics and Astronomy at Cardiff University and Science Made Simple. It is funded through the STFC's Science in Society Small Award Scheme.

The project has the following aims:

1. To raise awareness of the challenges faced by astronomers trying to detect gravitational waves and explain what the discovery could mean to our understanding of the universe.
2. To challenge secondary school students with materials that explain how Newton's model of gravity does not give the whole picture.
3. To use gravitational waves to engage students with astronomy, physics and engineering
4. To demonstrate some real-life applications of Einstein's theories.
5. To help teachers address some contemporary areas of cosmology.
6. To show students how the process of science works.

The project is developing an interactive 50 minute show to communicate its messages and explain the science of gravitational waves to 14-19 year old students and their teachers.

This report summarises the main conclusions from the evaluation of the piloting of the 'Gravity Beyond the Apple' show. Individual evaluation reports from two stages during the pilot phase are included in the appendices.

2 The evaluation

The evaluation used a mixture of quantitative and qualitative approaches to address these questions to address the following questions:

1. Did the project effectively meet its six key objectives?
2. What was the impact of the show on its various target audiences?
3. Did the show represent an appropriate medium for communication of the project messages?
4. What lessons/good practices are there from this project that would be of use to future practitioners?

The evaluation was formative and took place during the pilot phase of the project up to February 2009. It comprised observation of shows by the evaluator, completion of student and teacher feedback questionnaires and a focus group and interviews with students.

- The evaluation report for performances of the show in September 2008 is included in Appendix A.

- The evaluation report for performances of the show in February 2009 is included in Appendix B.

3 Conclusions about aims

This section comments on the extent to which Gravity Beyond the Apple met its original aims.

Aim 1: To raise awareness of the challenges faced by astronomers trying to detect gravitational waves and explain what the discovery could mean to our understanding of the universe.
In the main, this aim has been met. The show that is being developed by Sciencemadesimple includes information about and examples of the research that is being conducted into gravitational waves. There is evidence that students enjoy this aspect of the show and that those in years 12 and 13 could cope with even more content about this research. The inclusion of footage of researchers and their opinions could strengthen this aspect of the show.

Aim 2: To challenge secondary school students with materials that explain how Newton's model of gravity does not give the whole picture.
This aims was met in that students of all ages indicated that they now know about alternatives to Newton's model of gravity. Including information about Newton's model helped to reinforce this message and provided context for the information about gravitational waves. This was particularly necessary for younger audiences.

Aim 3: To use gravitational waves to engage students with astronomy, physics and engineering.
The show is successful in engaging students from years 11, 12 and 13. However there is some evidence that younger, less able pupils struggle to understand the content and therefore are less likely to be engaged. The black hole content was considered to be particularly engaging.

Aim 4: To demonstrate some real-life applications of Einstein's theories.
The show was partially successful in meeting this aim, whilst real –life applications are included in the show, there are very few which could be described as day-to-day or ordinary. This lessens the engagement of pupils who do not already have a strong interest in physics or astronomy.

Aim 5: To help teachers address some contemporary areas of cosmology.
The content is welcomed by teachers, who believe that for Years 12 and 13 more time could be spent on gravitational waves. They also comment positively about the inclusion of material that is not directly relevant to the teaching curriculum.

Aim 6: To show students how the process of science works.
The show refers to differences of opinion amongst scientists but this aspect could benefit from video footage of scientists describing their opinions and explaining their differences.

4 General conclusions

This section draws some general conclusions about the whole project as well as some individual elements.

Gravity Beyond the Apple is successful as a mechanism for engaging school audiences with a difficult and complex subject. The show as it stands has a sound basis but further refining is possible. There is some evidence that the content and style of the show is better suited to AS and A level students and should be targeted at them and their teachers. This would increase the scope for including more challenging content, such as materials which illustrate the scientific process. Some elements of the show (e.g. the mirror trick, the ring tones) are

considered less successful and could be substituted with other more engaging and challenging aspects. The show could benefit from a stronger ending. Perhaps a concluding question could be used to reinforce differences of scientific opinion and to encourage audiences to think about answers.

The involvement of the scientists in the development of the show has been successful. Their input has ensured scientific integrity has been maintained.

5 Appendix A - Evaluation Report of Presentations made 18 and 19 September 2008

These shows evaluated in this stage of the evaluation took the form of partially developed presentations by two different presenters. The objective of these sessions was to obtain audience feedback prior to Science Made Simple fully developing a show for 14 to 19 year old audiences.

The evaluation took the form of observations of two shows, plus questionnaire surveys and interviews with students and teachers. Show 1 refers to the presentation by Huw James on 18 September and Show 2 refers to the presentation by Helen Lloyd on 19 September.

1. Observations

This section includes the evaluators' thoughts on both days.

1.1 Show 1

- Logo is really attractive and bright but text component does not show up on a black background.
- Introduction too long – Argos catalogue demo not needed. Just need to give context, they all know Newton already. Better once it 'got going'.
- Demos a bit predictable. Could the 'Earth and Rocket' be run in parallel to reduce time? Also hard to see for students at back of theatre. The card 'graviton' would be better replaced by a coloured sphere.
- Blue circles 9 orbits on slides) do not show up well.
- All very rushed. No natural pauses for audience to absorb and reflect on what they are being told.
- Ends of some sentences were not audible.

1.2 Show 2

- See above for comments on logo and demos. Ball graviton better than card but still hard for audience at back to see. Needs to be held above heads and be brighter.
- More time allocated to explanation of terms and pauses to absorb information made understanding easier.
- Technical breakdown shows how much this subject relies on visual for comparison. Maybe worth asking Sathya and other researchers to describe exactly what they see/visualise when they think about these things.
- Photos of every large interferometer a bit repetitive and probably not necessary.
- If LISA is the latest technology, why doesn't it see as far back as LIGO.

1.3 General

- Looking more like a sciencemadesimple product than a university lecture.
- Audiences appear attentive and interested throughout.
- Light on interactivity.
- Sound could enhance the impact of some of the visuals.
- Really difficult to generate questions from a mixed (schools and ages) audience.

2. Student Questionnaires

2.1 Demographics

The respondents comprised 44 students (22 for each show) in years 10 to 13 and aged 14 to 18. A breakdown for by gender, age and year group is shown below. Males slightly

outnumbered females in the total and the most common age was 16 (47.7% of all respondents).

Gender

	Female	*Male*	*All*
Show 1	11	11	22
Show 2	10	12	22
Total	21	23	44

Age

	Show 1	*Show 2*	*Total*
Age 14	1	0	1
Age 15	6	4	10
Age 16	13	8	21
Age 17	2	9	11
Age 18	0	1	1

2.2 Ratings

Show 1

	V.good	*Good*	*Ave.*	*Bad*	*V. Bad*
Overall impressions	12	8	2	0	0
Presenter	12	7	3	0	0
Relevance to curriculum	4	8	7	0	3
Duration/Length	7	11	2	0	2

Show 2

	V.good	*Good*	*Ave.*	*Bad*	*V. Bad*
Overall impressions	8	13	1	0	0
Presenter	14	7	1	0	0
Relevance to curriculum	1	13	8	0	0
Duration/Length	8	9	3	2	0

Respondents were asked to comment on their ratings.

Most positive comments referred to the subject and the presenters. The subject was praised for being interesting or new and the presenters were generally well liked. Two respondents from Show 1 said the presenter was not always easy to understand and one from Show 2 said the presenter should have made sure the presentation worked (this was despite them being asked specifically not to comment on the technical breakdown).

Most negative comments referred to relevance to the curriculum. No Y11/10 students and only a few Y12/13 students said the subject was directly relevant to their courses. Those who did indicate that the subject linked to the curriculum said it was extremely relevant. The comments about length/duration indicated that the shows felt rushed and/or there was insufficient time to reflect on what had been communicated.

2.3 Descriptions

Show 1

	Very	*Quite*	*A little*	*Not at all*
Interesting	15	7	0	0
Interactive	4	15	3	0
Fun	8	12	2	0
Educational	12	7	3	0

Show 2

	Very	*Quite*	*A little*	*Not at all*
Interesting	8	12	1	1
Interactive	4	9	8	1
Fun	3	15	3	1
Educational	12	8	1	1

Reasons for the high ratings in the Interesting and Educational categories referred to the novelty and interesting nature of the subject. Reasons for the lower ratings in these categories referred to difficulty in understanding the subject.

Most respondents requested more demonstrations and experiments to improve interactivity and audience enjoyment.

2.4 Favourite aspects

- The most popular aspects in Show 1 were, in order: the Earth/rocket demonstrations; the black hole explanation; the animations in general.
- The most popular aspects in Show 2 were, in order: the videos; the gravitational forces demos involving the audience; hearing about the LISA experiment.

2.5 Least favourite aspects

- The least popular aspects in Show 1 were, in order: the introduction; the predictability of Earth/rocket demonstrations; time constraints; jargon not explained.
- The least popular aspects in Show 2 were, in order: the difficulty of seeing the demonstrations; and the description of the interferometer [this started without visual aid because of technical breakdown].

2.6 Suggested improvements

- Show 1:
    - Reduce introduction
    - Include more demos and things for audience to do.
    - Make sure everyone can see demos.
    - Explain all terms.
    - Allow more time to check audience has understood what is being said.

- Show 2:
    - Include more interactive activities, especially something that everyone in the audience can do.
    - Make demos a bit less predictable
    - Ensure everyone can see audience participation.
    - Use real numbers and make sure they are on screen as well as spoken to help us remember them.

2.7 Likelihood of continuing to discuss topic

12 respondents from Show 1 and 14 from Show 2 indicated that they would continue to discuss the presentation and topics that it raised. The remainder indicated that they were not sure.

2.8 Affect on interest in science

11 respondents from Show 1 and 14 from Show 2 indicated that the presentation had made them more interested in science. One respondent from Show 1 indicated that it had made them less interested and the remainder indicated that it had not affected their interest.

2.9 Learning

8 Respondents from Show 1 and 12 from Show 2 answered the question asking had they had learnt something. Their replies were:

- About gravitational waves.
- It takes 8 minutes for light to reach the earth.
- Not sure, I'm confused.
- How they use waves to look back in time.
- Newton was wrong about Gravity.
- A great many things about Gravity and its place as a dimension.
- Warping in space and time.
- That if the sun disappeared we would lose orbit 8 minutes later.

- Einstein reinvented theories of Gravity.
- More about gravitational waves.
- Not much. Contained too much jargon that I didn't understand.
- Gravitational waves exist. I also learnt the term graviton.
- The existence of solid plans for LISA.
- That space is distorted.
- There is more to gravity than I thought.
- Gravitons, gravitational waves, distortion of space.
- That exploding stars will send off gravitational waves.
- I learned a lot about gravity. Mainly gravitons, which I did not know existed.
- I already knew the things that were talked about
- That gravity waves exist and how they are affected by the mass of stars etc.

3. Student Interviews

The interview feedback (with 6 students at Show 1 and 10 at Show 2) was consistent with the responses to the questionnaires. It appears that some Examination Boards address Einstein's theories of gravity at AS level and others do not. The presentation managed to engage students who had studied the subject as well as those with no previous knowledge.

There was widespread agreement that the subject is difficult and that it is important for the presenters to explain terms and theories very clearly. It was suggested that the presentation should include activities to confirm what has been explained already (this was suggested by Y11 students, who were hearing the subject for the first time).

Students liked both presenters and could identify with them. Some members of the audience at Show 1 said that it was sometimes hard to hear the presenter.

Interview subjects in all Year Groups would like to have seen more demonstrations and to have increased levels of audience involvement. There was some feeling that ‘unpredictable’ demonstrations are the most interesting and that the Earth/Robot demos were too predictable.

It was good that the presentation started with Newton as everyone has studied this. However, the introduction in Show 1 spent too long on this aspect.

4. Teacher’s feedback

3 Teachers completed questionnaires and 5 were interviewed. With one exception (who saw Show 1 and thought the subject was much too complicated and the presentation lacked humour) their feedback was consistent with the provided by the students:

- Slides not very easy to read (black background may be a problem with coloured graphics).
- Needs stronger demonstrations. The Earth/Rocket demos may work better in parallel.
- Despite not being in WJEC curriculum, this is still worth teaching to students.
- Jargon needs very clear explanation.
- More natural pauses should be introduced to give audiences time to absorb information.
- An hour-long show will need more demos/audience activities to maintain interest and energy levels
- Some of the facts need checking, were all the quoted numbers correct?
- Presenter in Show 2 coped very well with technical difficulties, which highlighted how important visuals are for the communication of this subject.
- Starting with Newton is good but the introduction took too long (show 1).

6 Appendix A - Evaluation Report of Presentations made 18 and 19 September 2008

The stage of the evaluation took the form of:

- Observation of two shows (one on 9 February 2009 to year 11 pupils at Cathays High School Cardiff and one on 13 February to year 12 and 13 pupils at Haberdashers Monmouth School for Girls (HMSG)).
- Analysis of 58 pupil feedback questionnaires (47 from Cathays and 11 from HMSG).
- Focus group with 11 AS and A level pupils at HMSG.
- Discussions with 4 teachers (1 from each of Cathays, HMSG, Wycliffe College and Treorci Comprehensive)

1. Observations

1.1 General

- The presentation is an interactive lecture and not a 'show' in the usual sciencemadesimple mode.
- Giving a route map of what is going to happen (i.e. 3 sections Gravity on Earth, Gravity in space and Gravitational Waves) is helpful in providing the audiences with a context.
- It is good to explain at the start that they will need to use their imaginations for Gravitational Waves section. However, they may need reminding of this at the start of that section.
- The first two sections are more entertaining than the final third, which needs more demos or activities to bring it alive in the same way as the first part of the show.
- Presenter dressing up as Newton is humorous and entertaining.
- Balloon race between Newtonian and Einsteinian gravity works well as a demo, but may be difficult for everyone in a large audience to see – perhaps the volunteers could stand–up to help visibility.
- References to 'things we can't go into today' or 'things that are too difficult even for university students', whilst reinforcing the novelty of the science could make the audience less inclined to see the subject's relevance to themselves.
- The videos of gravitational waves are a nice addition, but it is unfortunate when the voiceover commentary interferes with presenter's explanations.
- Black hole noises sound a little bit weak, unless the sound system is really good.
- Photos of the large interferometers are a bit repetitive and dull. What about some interviews with scientists who work there? They could provide some human interest and make the final third of the show more engaging.
- The show begins strongly but rather peters out. A strong ending is needed, perhaps two scientists presenting their different views and a question to the audience about which opinion they agree with. This would lead nicely into a Q & A

1.3 Audience Reaction

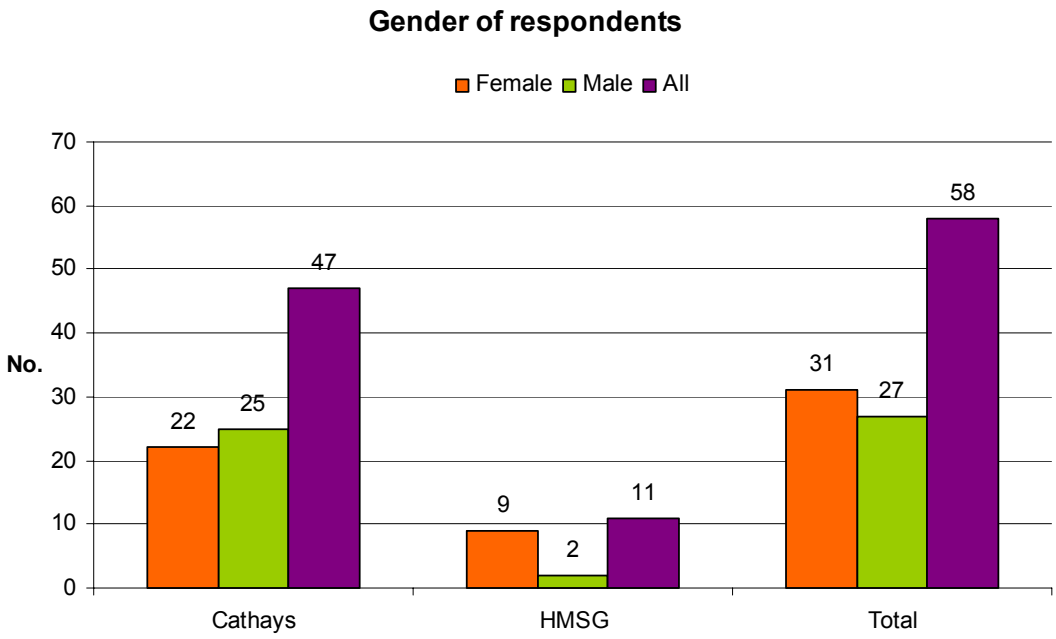
- A number of Year 11 pupils appeared bored in later stages of the show. Conversely, interest of older pupils increases as the show progresses.

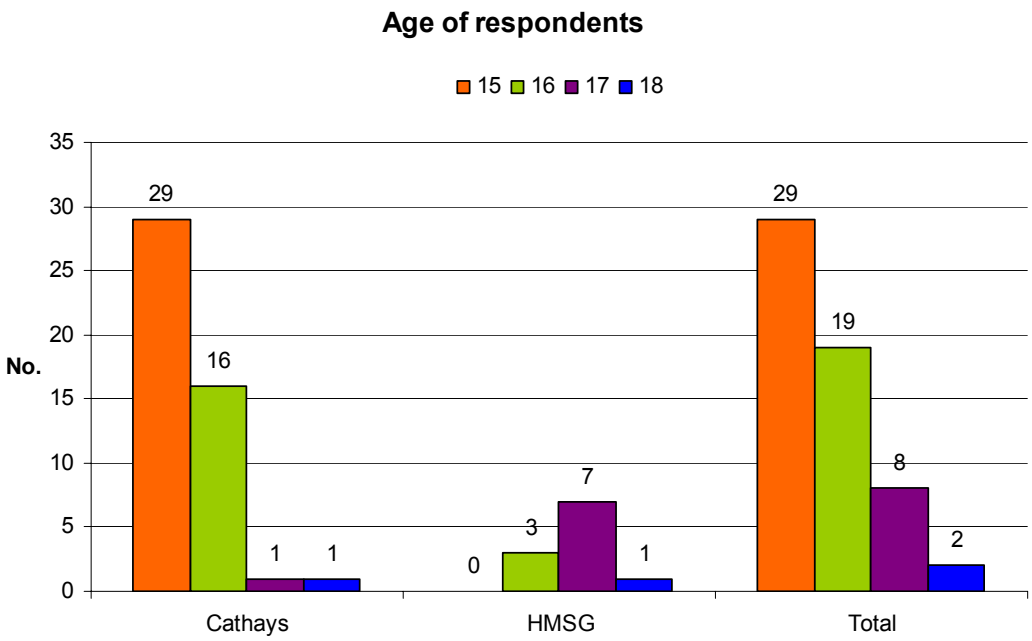
- Year 12 and 13 pupils were less keen to volunteer than younger pupils, which is not unique to this show.
- All ages obviously find the ring tones to be not cool. The presenter handles this well by sharing their view.
- Reaction to the inclusive experiment to find waves is pretty cynical, with comments about scientist taking the credit.
- Audiences need to be told the show has ended as it is not obvious to them

2. Pupil Questionnaires

2.1 Demographics

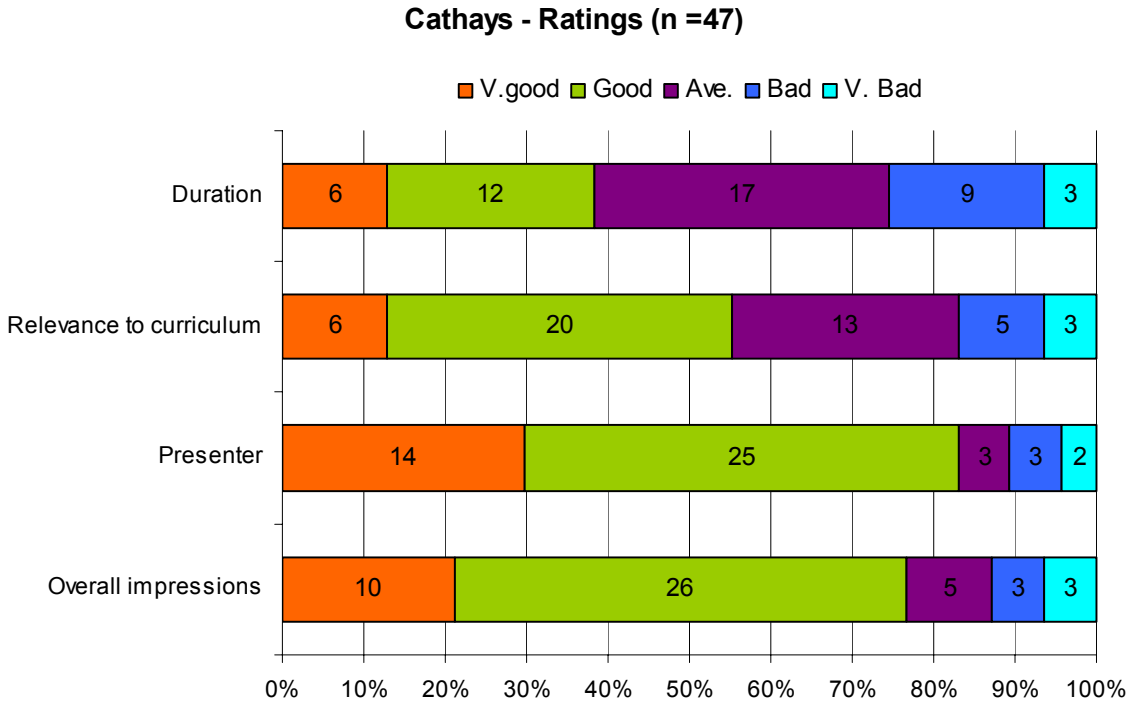
The respondents comprised 58 students (47 in year 1, 3 in year 12 and 8 in year 13). Breakdowns by gender and age are shown in the following graphs.



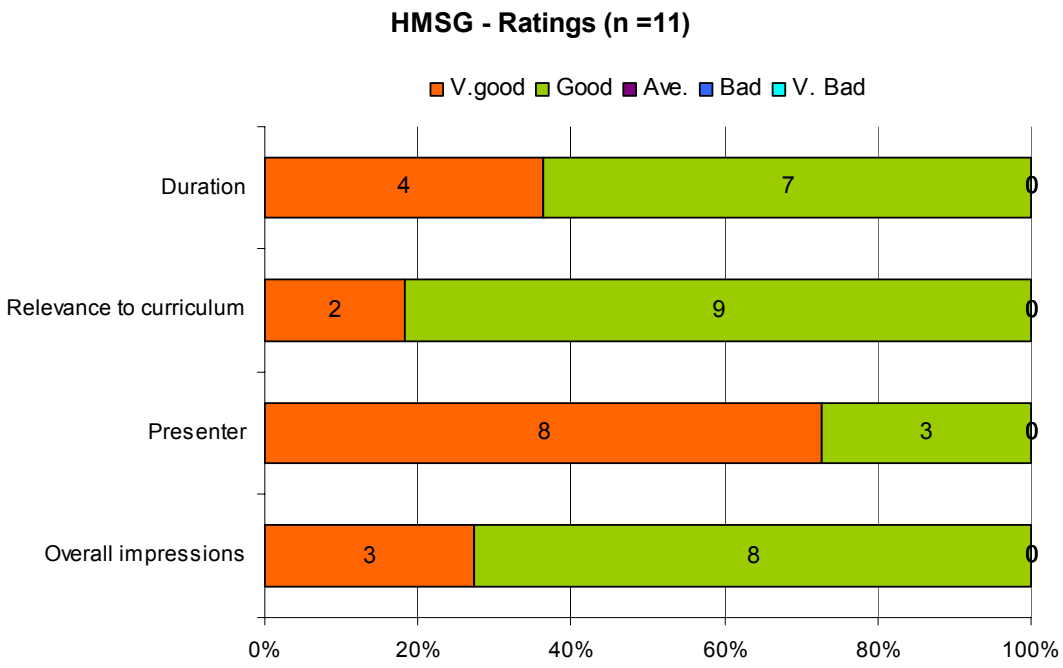


2.2 Ratings

Year 12 and 13 pupils were more likely to rate aspects of the show more highly than those in Year 11. Their ratings were borne out by the comments of the teachers who felt that some of the content was too difficult or advanced for all but the most able year 11 pupils (see section 4 of this report).



Those pupils who selected Very Bad ratings indicated that they found the show very boring and did not understand it.



Respondents were asked to comment on their ratings. Their comments are described below.

Cathays –Year 11

Out of a total of 47 comments, 23 were positive and 24 were negative.

The most frequent positive comment was a reference to the abilities of the presenter, followed by the interesting nature of the subject and next the way in which gravity was explained or simplified. Other positive comments mentioned fun or enjoyment.

The most frequent negative comment was a reference to the show being too long, followed by the fact that the content did not relate to what they were studying at GCSE and next the fact that it was generally boring. Other negative comments referred to requiring more demonstrations or interactivity and knowing the content already.

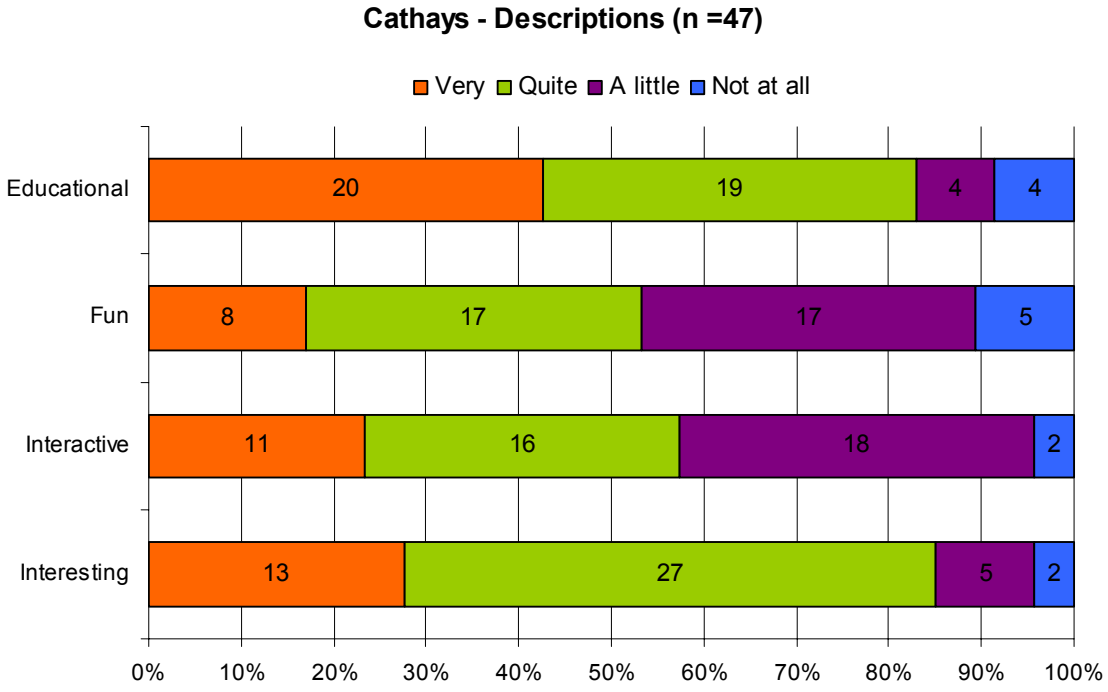
HMSG –Year 12 and 13

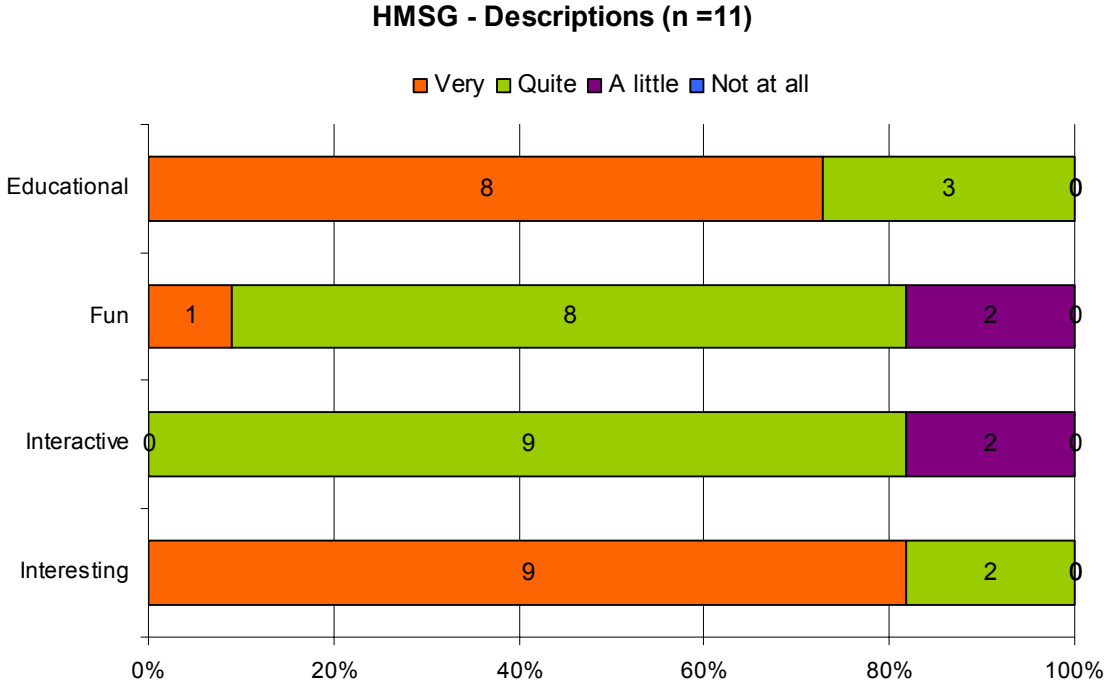
Other than two references to reducing the length of time spent on the introduction or Newton, all comments were positive.

The interesting nature of the subject was the most frequent positive comment followed by the skills and abilities of the presenter to explain it in a way that was entertaining and could be understood.

2.3 Descriptions

Respondents in all three years (11, 12 and 13) were more likely to describe the show as ‘very’ or ‘quite’ interesting or educational than ‘very’ or ‘quite’ interactive or fun.





Respondents were asked to comment on their rating of the descriptions. Their comments are described below.

Cathays –Year 11

Out of a total of 29 comments, 19 were positive and 10 were negative.

The most frequent positive comment was a reference to the amount of learning, followed by audience participation and next enjoyment of the show. Other positive comments referred to the respondents' general interest in physics.

The most frequent negative comment was too much talking by the presenter or insufficient demonstrations, followed by a general lack of enjoyment.

HMSG –Year 12 and 13

Other than three references to the interfering voiceovers on the video, all comments were positive.

Learning about gravitational waves was the most frequent positive comment and was mentioned by all respondents.

2.4 Favourite parts

45 respondents at Cathays answered the question about favourite aspects. In order of decreasing popularity, they were:

- Shooting the monkey
- Practical demonstrations in general
- Information about black holes
- Presenter dressing as Isaac Newton
- Nothing
- Everything
- The gravity race

All 11 respondents at HMSG identified favourite aspects. In order of decreasing popularity, they were:

- The interesting and new (for AS students) nature of the gravitational wave content
- The presenter
- The lecture-style of the presentation

2.5 Least favourite parts

40 respondents at Cathays answered the question about least favourite parts, which in order of decreasing popularity, were:

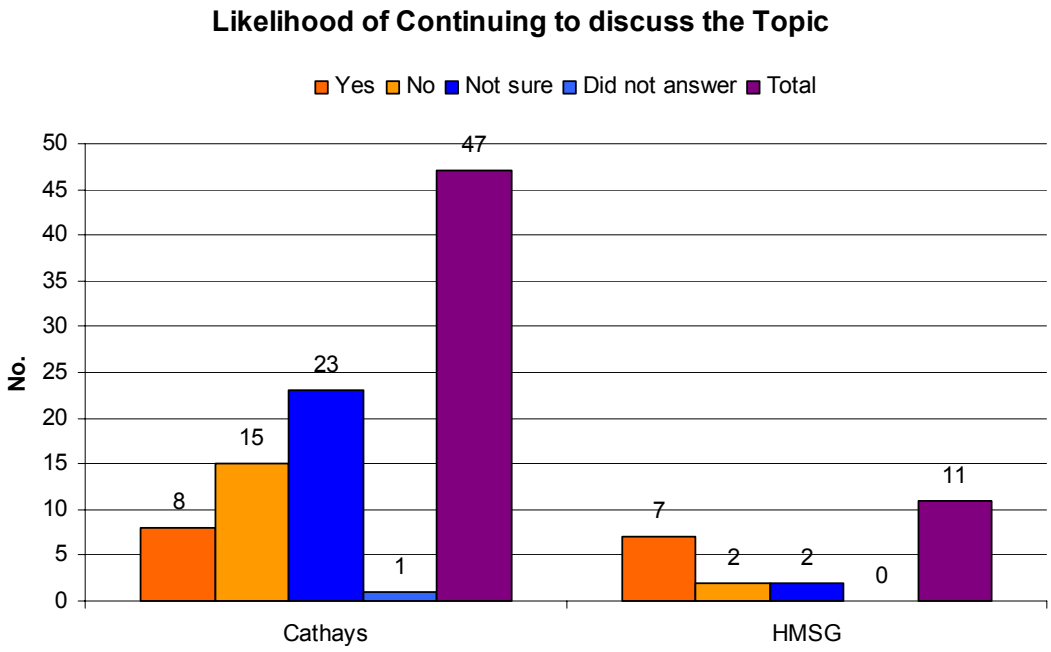
- Nothing
- The trick with the mirror
- Presenter talking without demonstrations
- Ringtones
- Black hole noises
- Everything
- Presenter dressing up
- Gravity race
- Nothing

All 11 respondents at HMSG identified least favourite aspects. In order of decreasing popularity, they were:

- The first part (Newton) which was too easy.
- The monkey demonstration, which they had already seen
- The ring tones
- The ending

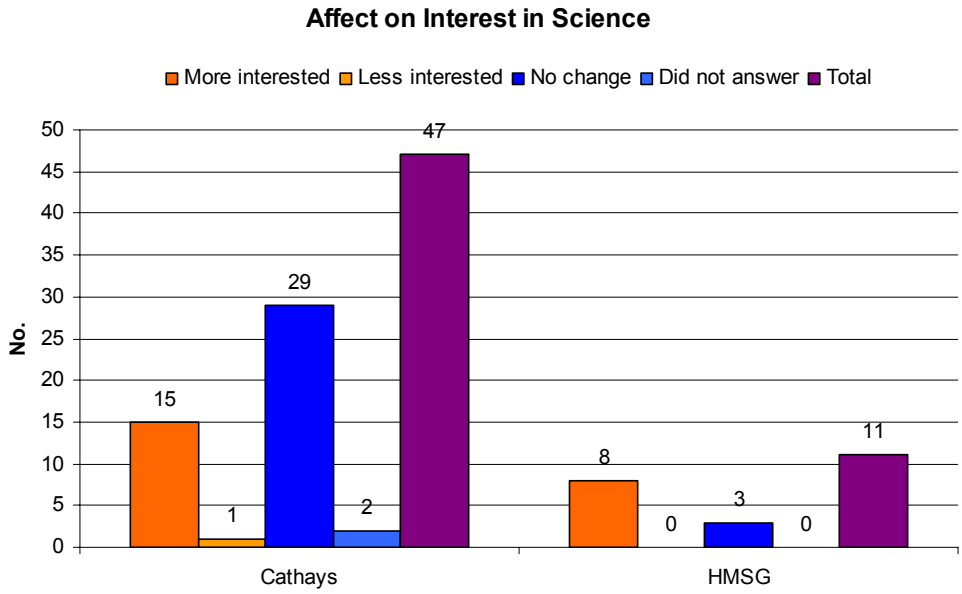
2.6 Likelihood of continuing to discuss topic

8 respondents at Cathays and 7 at HMSG indicated that they would continue to discuss the presentation and topics that it raised.



2.9 Affect on interest in science

15 respondents at Cathays and 8 at HMSG indicated that the show had increased their interest in science, only one respondent (at Cathays) said it had made them less interested – see graph overleaf for details.



2.8 Learning

31 respondents at Cathays answered the question asking had they had learnt something. The most common response (8) was more about gravity; next most common (7) was generally positive comments such as 'lots' or 'a lot'. It was followed by generally negative comments (5) such as 'nothing' or 'nothing new'. Other answers were 'waves in gravity' (4), black holes (3), the weakness of gravitational force (2) and something about the Universe (1) and science is modern (1).

All respondents at HMSG answered this question. All 3 Year 12 pupils said they had learnt about gravitational waves for the first time. All year 13 pupils indicated that they had learnt about the LISA experiments.

2.9 Suggested improvements

40 respondents at Cathays answered a question about suggested improvements to the show. 5 answered nothing and 7 indicated they didn't know how to improve it. Other responses were:

- Increase interactive elements (11)
- Make it shorter (9)
- Make it more relevant to GCSE syllabus (3)
- Add music to the videos (2)
- Make the end part more interesting (2)
- Avoid jokes you know won't work (1)

All 11 respondents at HMSG answered this question. Their answers were:

- Remove voice overs on video clips (4)
- Have a better ending (4)
- Reduce the length of the introduction about Newton (3)

5. Pupil Focus Group

The Focus Group feedback (with 11 students at HMSG) was consistent with the responses to the questionnaires. It appears that some Examination Boards (e.g. Edexcel) address gravitational waves at AS level and others (e.g. AQA) do not. The presentation engaged Year 13 students who had studied the subject already as well as those in Year 12 who had no previous knowledge. (*'It was useful revision for us in Year 13'. 'I enjoyed learning something new'.)*

It was good that the presentation started with Newton as everyone has studied this, although there was widespread agreement that the introduction could be reduced for A and AS Level pupils, with a greater emphasis placed on the gravitational waves and current research section. It was thought that the gravitational waves part contained the most interesting content, but it was presented in the least interesting way. *'pictures of large interferometer equipment are not very inspiring – they all look the same'.*

When asked what elements, if any, they would remove from the show, all agreed they would drop the monkey *(it's in our text book anyway and didn't work), the ring tones ('awful', 'really bad'*) and the information about the participatory experiment to find waves (*'I can't leave my computer on all the time', 'even if you found them some scientist would take the credit'*).

Students liked the presenter enjoyed the lecture style show (*'It's like being at University – not school which is different from usual lessons'*). They thought it would be too advanced for GCSE pupils ('*they'd get bored and wouldn't understand it'*). They also thought the one hour was the maximum it should take, with 45 to 50 minutes preferred.

They were all happy with the level of interactivity and would not want to see increased levels of audience involvement. When asked how the section about Gravitation al Waves and current research could be improved, suggestions included *'include some of the stuff she said was too difficult or still being researched, get scientists to tell us what they are doing', 'show some scientists doing experiments or at least talking about them'*, *'it needs an obvious ending, we weren't sure she had ended'.*

All pupils would like to see a similar activity repeated at their school, particularly if it was to address particle physics. Some are considering studying science subjects at University and anything that presents latest research or thinking in all areas of science would be welcomed.

6. Teacher's feedback

1 Teacher completed a questionnaire and 4 were interviewed. Their feedback was consistent and can be summarised as follows:

a. The gravitational waves content goes over the heads of all but the most able year 11 pupils. Despite this most of them enjoy the show. It also revises aspects of gravity that they have studied.

b. The coverage of up to date research which is beyond even the A level syllabus is welcomed for A and AS level pupils, although it is questionable how well younger pupils can relate to it.

c. One hour is along time for younger pupils to remain engaged, it is obvious that all but those who are most interested in physics become bored after 40 minutes.

d. The variety of techniques used by the presenter (video, demos, visuals and talking) is praised and is thought to help make a difficult subject less confusing than it could be. The 3D images of gravitational waves are considered to be particularly good.

e. The thought provoking nature of the advanced content of the final third is good for AS and A level students, but does not make an impression on most Year 11s.

f. For A and AS Level students more time should be spent on gravitational waves, explaining some of the things that the presenter described as ‘too difficult’.

g. It is recognised that it is difficult to pitch this show for less able Year 11 pupils. Perhaps the advertising should target Years 12 and 13 and say that the more able Year 11 students could also benefit from it.

h. The interactive -lecture style is felt to be a good introduction to university life.

i. The ending needs to be developed. It should be obvious that the show has ended.

j. Showing real scientists (as opposed to equipment) would create some role models and reinforce the suggestions that the pupils could be carrying out this type of research themselves in the future.