



Meteorites

Front-end Evaluation Report

Life Galleries Redevelopment
August 2005

Introduction

This report presents and analyses findings from the Front-End evaluation of the meteorites and planetary science project. It is planned that the current meteorites gallery will be closed and a new meteorites and planetary science gallery opened in the Earth Galleries part of the museum.

The aims of the evaluation were to:

1. Find out visitors current level of knowledge and understanding of meteorites and planetary science.
2. Find out what visitors' expectations of a meteorites exhibition at the Natural History Museum would be.
3. Find out what would bring visitors to an exhibition on meteorites and planetary science.

It is hoped that the results will allow the project team to make better informed decisions with regard to content and design of the exhibition.

Methodology

Visitors to the Natural History Museum (NHM) were approached at random and invited to take part in an interview, which consisted of card sorting tasks and qualitative, open-ended questions. Visitors who were alone and in groups were approached and interviews took place during the week and at weekends. A total of 44 visitors in 20 groups were interviewed. (See Appendix 1 for the questionnaire).

Visitors were shown some stimulus material to help to focus their thoughts. This consisted of several photographs of meteorites and craters and an example of a stony meteorite for them to hold.

Visitors who had and had not visited the Museum's current Meteorites Pavilion were interviewed.

Other relevant studies

Some of the questions in this study were similar to a front-end evaluation study into meteorites carried out at the American Museum of Natural History (AMNH) in 2002. Where appropriate, visitors' answers to questions will be compared. The AMNH survey is much larger and so provides more robust data set.(sample = 112). However, differences between the methods of collection and between a UK and US audience must also be taken into consideration.

In addition, where appropriate, reference will be made to a report carried out by Creative Research for the Particle Physics and Astronomy Council in 1998 into visitors' understanding of key terms. In Appendix 2, please also find a summary of chapters 1 and 6 of the SPACE report into children's understanding of key concepts relating to the Earth in Space attached for background information. This has been provided by Phil Holmes.

Findings

Demographics

Visitors from a variety of ages and in a number of different sized groups were interviewed.

Age	5-11	12-16	17-24	25-34	35-44	45-59	Over 60	Total
Males	6	3	1	3	6	2	1	22
Females	2	1	5	4	6	2	2	22
Total	8	4	6	7	12	4	3	44

nb It must be noted that the sample size is small and results should be treated with caution and not generalised.

Sixteen of the 20 groups were asked where they came from. Of the 16 groups, most were British and the remaining spoke excellent English.

Where are visitors from?	Number
London	4
Other UK	6
Other Europe	4
Americas (North and South)	2

Visitors were also asked if they had any special interest or training in science. Of the 5 who answered that they did, 1 group were science students, 2 visitors were teachers and one worked in Chemistry. The vast majority, however, had no special interest or training. It must be noted, however, that visitors to the Natural History Museum are likely to be more highly educated than the general population.

Only 4 groups of visitors had visited the Meteorites Pavilion before the interview, 3 that day and 1 on a previous visit. After the interview, however, several groups expressed an interest in visiting it. There appeared to be no difference in knowledge or expectations among visitors who had previously visited the gallery and those who had not.

Visitor Knowledge and Understanding

In order to get visitors thinking and discussing meteorites and planetary science, they were asked to write down things that came into their heads when they heard, first the word “meteorites” and then “planetary science”.

When thinking about meteorites visitors approached them in 3 main ways. These were:

1. Thinking about aspects of meteorites specifically (45/82 answers)
2. Thinking about other aspects of space (25/82)
3. Questions they had about meteorites (12/82)

Many groups included all 3 types of answer on their sheets.

When thinking about meteorites specifically, approximately one quarter of the answers referred to what meteorites were made of (11/45). Most of these answers referred to iron, although one visitor did think they were made of ice.

Another popular answer was for visitors to think about meteorite craters and impacts (10/45). In particular, 2 groups of visitors mentioned Arizona as a place where they believed there to be many craters.

Visitors often appeared to have a lack of confidence with the subject matter of meteorites, leading to some writing very simple answers and not many words on their sheets of paper. For example 6 visitors wrote the word “rocks”.

Five groups of visitors (approximately a ¼ of the sample) mentioned and wrote down dinosaurs during the discussion and specifically the theory that a meteorite had led to their extinction. It is not known if they had visited the Museum’s Dinosaur Gallery before being interviewed.

Thinking about meteorites often prompted visitors into writing down the names of other bodies and areas in space (14/85). For example, asteroids (n=2), comets (2), planets (2). In addition 7 groups simply wrote down the word space, perhaps signifying that they had a vague but not fully defined idea of where meteorites came from.

Visitors also had questions about meteorites that they spontaneously wrote on their sheets and these are listed below. They illustrate well the range of comments that were written on the sheets.

“What causes them?”
“Could they wipe out the human race?”
“When will a meteorite next land on our planet?”
“Are they pieces of other planets that have fallen off?”
“What are meteorites made of?”
“How do meteorites catch fire when falling?”
“What happens when they land?”
“What causes them?”
“What damage have they done?”
“Where do they come from?”
“What is the impact on our planet, culture and society?”
“What is the largest known?”

The fact that most visitors wrote down very vague and general words associated with meteorites and space, along with the questions they asked seems to show that while visitors know a little about meteorites, they are not confident in that knowledge and feel insecure when discussing it.

Visitors were asked to complete the same exercise for the phrase “planetary science”. This, more general phrase seemed to confuse visitors more than the term meteorites. There were several blank looks and a few visitors asked the interviewer what it meant before attempting to write anything down.

Visitors’ answers can be broadly divided into 4 categories.

1. Words associated with space (31/65)
2. Words associated with studying space (13/65)
3. Characteristics of planets (12/65)

4. Questions (9/65)

The largest category are simply words associated with planets and space (31/65) such as stars (4), solar system (6) and galaxies (3). The words were generally written down in a list with no context applied to any of them.

Visitors also wrote down words and phrases associated with the study of planets and space (13) such as exploration and discovery (4), astronomy (2) and white coats (1). This seemed to show a slightly clearer understanding of the term, as visitors were able to define more clearly what might happen in planetary science.

Some visitors (12/65) also mentioned the characteristics of planets such as their composition, atmospheres and environment again perhaps showing a clearer understanding of the term. Visitors often had more than 1 type of answer on their sheets.

Similarly to the meteorites sheets, some groups wrote specific questions about planetary science (9) and these are listed below.

“How old are planets?”

“What instruments are used to explore them?”

“What are planetary sciences?”

“Why are they not all the same size?”

“Did one planet derive from another?”

“What are they made of?”

“How long have they existed?”

“What is the Big Bang?”

Overall, the lack of detail on the sheets filled in by visitors seem to show that most of them have a sketchy and basic understanding of meteorites and planetary science and the difficulty some visitors had in writing anything at all shows it is certainly not a topic at the forefront of visitors' minds when they are visiting the museum.

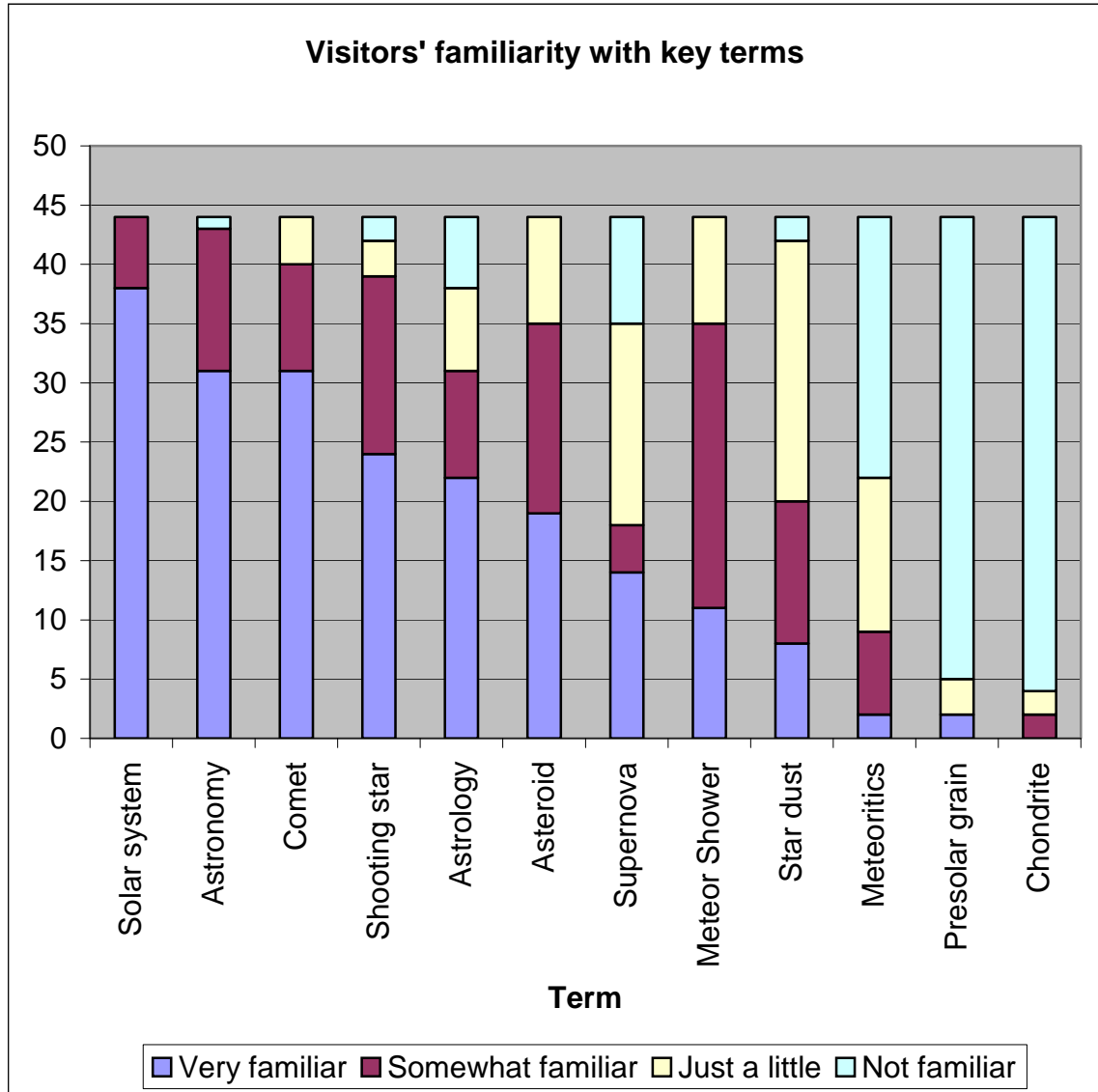
When compared to the AMNH survey which lists visitors associations with the term meteorites it can be seen that most visitors there also came up a general statement – that meteorites come from outer space. (61%). However there were different frequencies with the way visitors mentioned craters or metals for example. This is probably due to the fact that in the NHM survey visitors could talk amongst themselves, probably for a longer period of time before the question was completed. Also at the NHM visitors filled in this question themselves.

Familiarity with key terms

Having asked visitors in depth about what they associated with the terms meteorites and planetary science and thus understanding more about their level of knowledge; visitors were then asked to rate their familiarity with a range of other related terms, some of which they had already mentioned themselves in the earlier question. This was done by means of card sorting, where visitors were given terms on a card and asked to sort them into 4 groups; very familiar, somewhat familiar, just a little and not at all familiar. Visitors' answers have been analysed as 44 individuals rather than 20 groups for this question.

Due to time constraints, visitors were not asked to prove their knowledge and understanding of the terms.

Graph 1



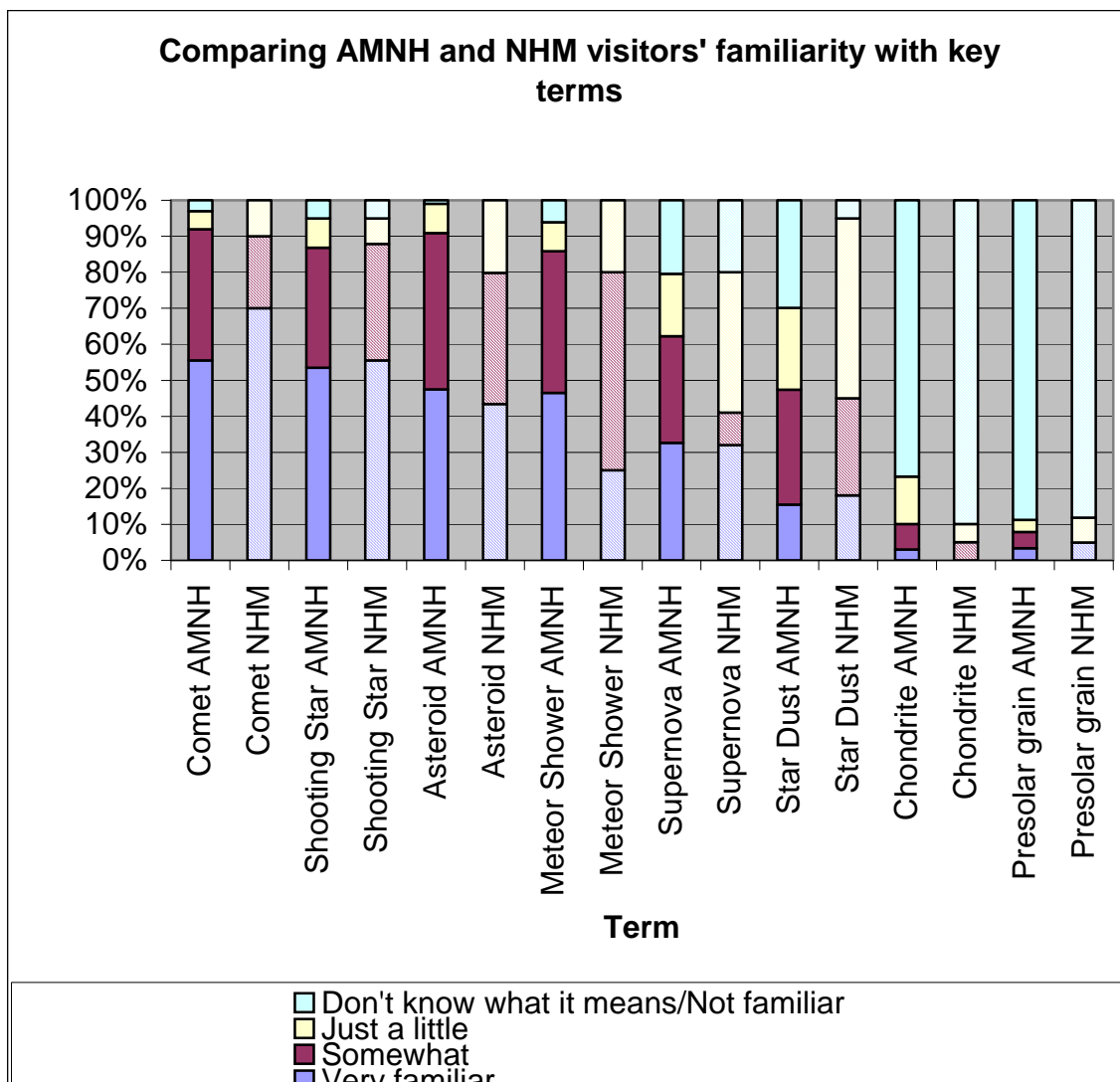
In the graph above, it can be seen that visitor's familiarity with the terms differed a lot. As might be expected, children were generally less likely to be familiar with the term than adults, although were sometime less honest when they sorted the cards!

It can be seen that visitors were very familiar with the terms solar system, astronomy and comet and fairly familiar with astrology, shooting star and asteroid.

Visitors had very little knowledge of the terms chondrite, presolar grain and meteoritics.

Visitor's familiarity with some of the key terms can be compared with a similar question in the AMNH survey. In order to compare visitors' answers, the findings from the NHM survey have been changed into percentages (The NHM sample should not usually be thought of in terms of percentages due to the small sample size).

Graph 2



It can be seen when comparing the two studies that they broadly follow the same pattern with visitors in the UK and the US having familiarity with comet, shooting star and asteroid and less familiarity with star dust, chondrite and proesolar grain.

There are several key differences between the results. In the UK, visitors seemed more reluctant to place their card in the not at all familiar pile. This could be due to the differences in terminology of the question or the US visitors being less afraid to show their lack of knowledge and placing words in the 4th rather than the 3rd category. It would seem unlikely though, that the UK visitors are substantially more familiar with these phrases, although it is possible.

When one looks at the percentage of visitors to both institutions who were very or somewhat familiar with the terms we can see that in all but the asteroid category they add up to a very similar percent.

This seems to indicate that the level of understanding among visitors to the 2 institutions is broadly similar and also that, despite the smaller sample, the UK survey is accurate in terms of the number of visitors who feel familiar with the topic.

Visitors at both the NHM and AMNH were not asked to prove their familiarity with the terms. During the card sorting exercise at the NHM, visitors did not know in advance that they would not be asked for the meanings of the words so it is hoped they were honest. This does not take into account visitors who have a misguided view about what the terms mean.

A survey of visitor knowledge carried out by Creative Research for the Particle Physics and Astronomy Research Council in 1998 also tested visitors' knowledge on some key terms such as galaxy, planet, proton, solar system and star.

Although most of the terms were different, they related to a similar field and visitors had to describe how familiar they were with the chosen terms on a similar scale. This study then invited those participants who said a word or phrase was familiar to them to give a definition which was then scored against a model definition.

This study found that in most instances the score of participants against the model definition was less than 2/7 (where 7= the model definition).

"Bearing in mind that we only asked for definitions from those people who felt that had a reasonably good idea of the meaning of each concept, this suggests that levels of understanding are low." (Creative Research, 1998)

Although the Creative Research findings do not mean that our visitors have low understanding, it is important to bear in mind that visitors often have ideas, which are misconstrued. Visitors' lack of detail in the previous question also points to the fact that while visitors have heard of many of the relevant terms they are not clear about exactly what they mean.

This could present a problem when delivering an exhibition for if a visitor believes that they already know what, for example, an asteroid is, they may not read an introductory explanatory piece of text explaining a term. In addition, perhaps previous incorrect or incomplete knowledge they come with could have an impact on their understanding of the exhibition as a whole.

Visitors' questions about meteorites

Visitors were asked if they had any questions about meteorites that they would like to know. It can be seen from the table above that visitors had many varied questions about meteorites showing wide ranging interest. (Visitors' questions from earlier in the interview have not been included here as the questions were often repeated).

Visitors tended to want to know about meteorites in particular rather than more general planetary science questions such as what they are made of.

"Where do they come from?"

"Are they made of the same materials as earth rock?"

Four visitors wanted to know how we know about various aspects of meteorites.

“How do they date them?”

A further 4 took a more alarmist approach.

“Could they threaten our life?”

The questions seem to show that visitors are interested in meteorites and seem more interested in the basic information about meteorites themselves and have not considered how this information could be used more widely in a planetary science context.

Visitors’ expectations

Visitors were asked what kind of exhibition they would expect to see on meteorites at the Natural History Museum. It was explained that the museum currently has a meteorites gallery but that it may be enlarged and updated. The results from this question were used to compare with visitors’ expressions of interest later in the survey to assess if what visitors think they will see at an NHM exhibition matches what they are most interested in. This will be dealt with in the next section.

Of the 64 comments about visitors’ expectations 39, or about 60% referred to the design of the space or media used to get the messages across. The remaining 25 dealt with expectations of content.

Nearly half of the groups (9/20) said that they expected to see real specimens.

“Real samples”

About 1/3 of the groups (7/20) mentioned that they would expect to see pictures of meteorites and related topics. A further 9 groups mentioned expecting to see hands on or interactive elements. This referred mainly to being able to touch specimens, although a few quotes mentioned interactives or games.

“Hands on, things to touch...”

The remaining answers were only given by 1 or 2 groups and are listed below.

Intro screen, models, quizzes, action, maps, explosions, lights, videos, planetarium, props, demos, explainers

In terms of the content and messages that the Hands On specimens and pictures would get across, there was again much variety in visitors’ answers.

Four groups expected the content to deal with what meteorites are and a further 4 thought they would see details about craters.

“Meteorites map with impacts marked”

Three groups expected to find out about the origins of meteorites.

“Explanation of what they are”

Again, the remaining ideas for content were only given by 1 or 2 groups and are listed below.

Human stories, composition, origin of solar system, impacts, asteroids, history of discoveries, how we understand them, speed, size, aliens, climate change

What would make visitors come to an exhibition about meteorites?

Visitors were asked “if there was one thing that would make you visit an exhibition about meteorites what would it be?”

Interestingly, out of the 33 responses, only 4, or 12% were about the content of an exhibition, compared with the 40% who mentioned specific content in their expectation of an exhibition.

The vast majority of the groups mentioned the design and media of the exhibition. This shows that for a general, non-specialist museum audience the way a gallery is presented can be more important than the content for them.

The most popular answer visitors gave was a meteorite to touch – or rather a range of different specimens to touch (8/33).

“Things to touch, real meteorites”

This was interesting as most visitors had not been that excited when given a meteorite to hold as stimulus material.

Four groups mentioned that they would like some kind of tour or talk from staff to help them to understand meteorites.

“Someone speaking on it like once an hour”

A further 4 felt that having great audiovisuals was very important and five groups mentioned that the gallery should be hands on and interactive. Of these 2 groups specifically mentioned computer interactives.

“Watching them falling out of the sky.....something with a bit of pop to it”

Other answers, given by only 1 or 2 groups are listed below.

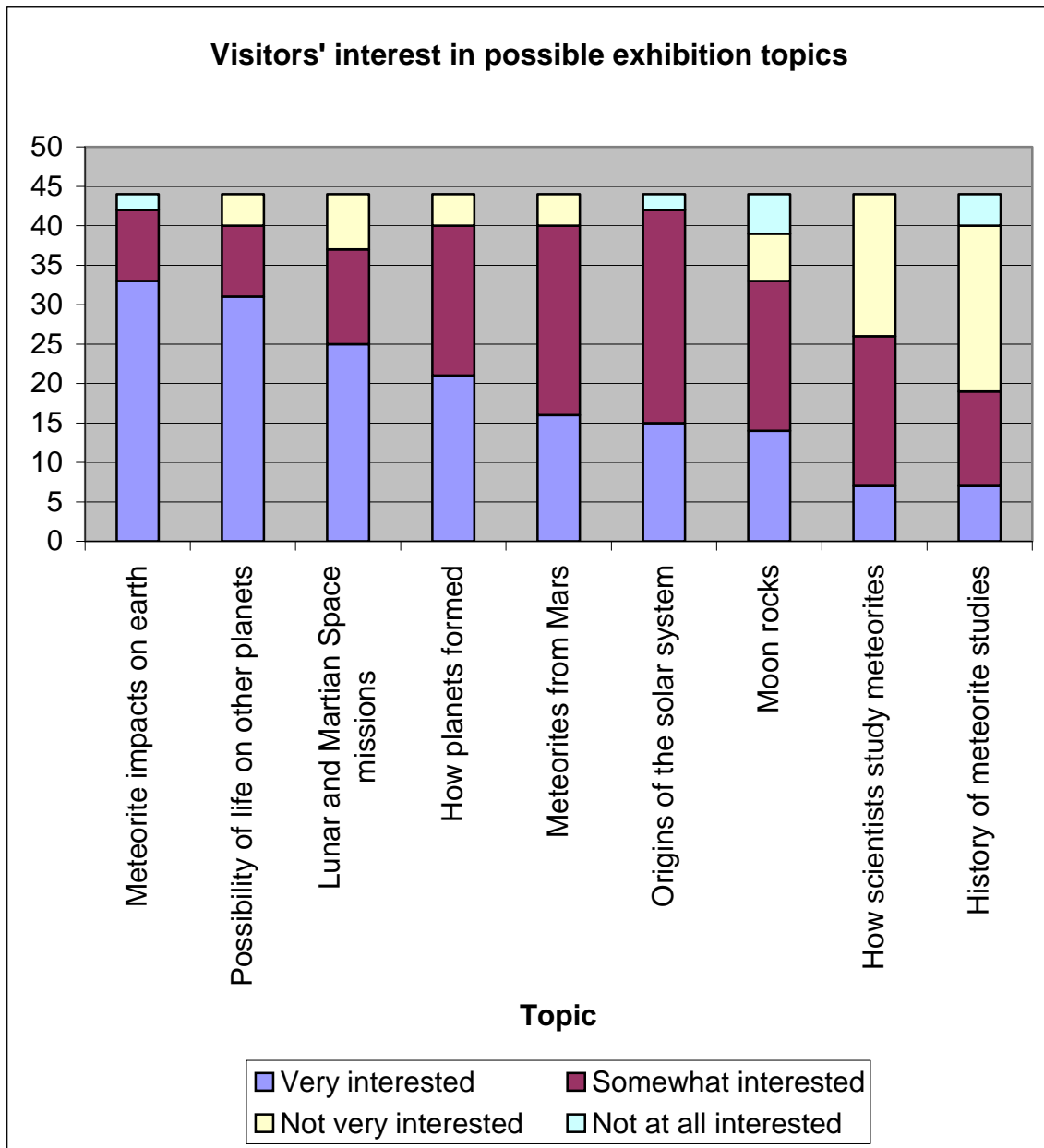
Stories of landing, simulations of an impact, origins, possibility of life on other planets, film, 3d, colourful, large objects, nothing in particular, challenging advert

Although when asked in an open ended way about the exhibitions, visitors concentrated on the design, they did show interest in content. Visitors were asked to rate their interest in a number of possible content topics for the gallery by sorting topics printed on cards into “very interested”, “somewhat interested”, “not very interested” and “not at all interested”.

These have also been compared with answers to a similar question asked in the AMNH survey. Some different topics were used in each survey, however.

It can be seen from the graph below that the topics visitors were most interested in were meteorite impacts on earth and the possibility of life on other planets. About $\frac{3}{4}$ of visitors put them in the “very interested” category. (33/44 and 31/44).

Graph 3



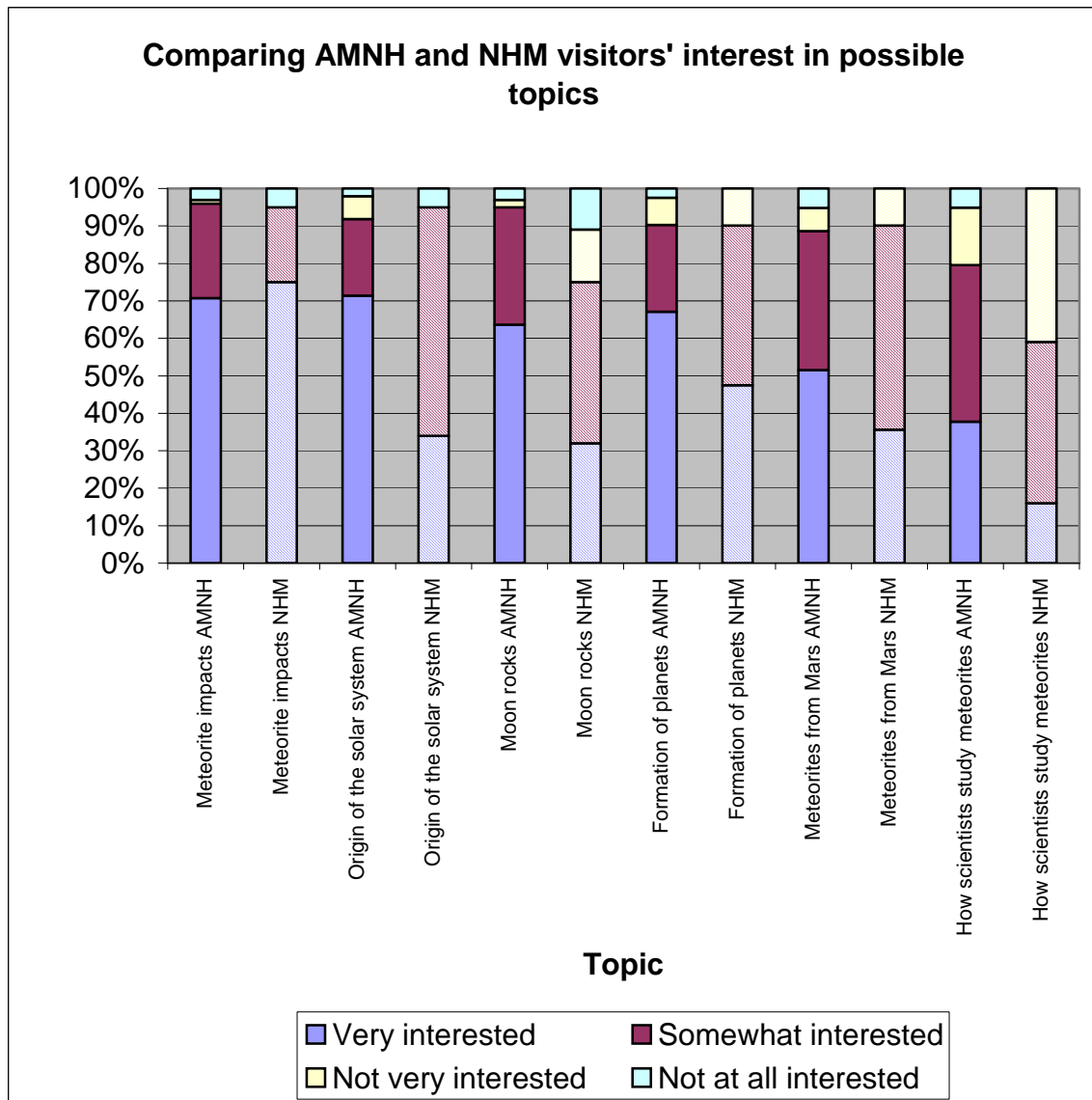
Only moon rocks, how scientists study meteorites and the history of meteorite studies attracted a significant number of people who were not very interested in them. The history of meteorite studies and how scientists study meteorites were the only topics to have more than 25% of visitors say they were not interested in the topic. For scientists studying meteorites 18/44 were not very interested and for the history of meteorite studies visitors were even less interested with 25/44 rejecting the topic as uninteresting.

Children were the most likely to be uninterested in the topics about studying meteorites.

As can be seen earlier in the report, visitors were interested in the outcomes of scientists' work as they had many questions, which could only be answered by

scientists. From this evidence it seems as though visitors are more interested in the outcomes of scientific work than the process of the work itself or its history. In addition, design interpretation methods formed an important role in making visitors come to an exhibition, rather than the content.

Graph 4



Some of the topics which visitors were asked to rate their interest in were the same as those used in the AMNH survey and these visitor ratings have been compared in the graph above. It can be seen from the graph that in terms of being broadly interested or otherwise in a topic, (i.e. looking at the first two categories together), visitors had similar ideas about the areas they were interested in.

In both museums, visitors rated meteorite impacts as the area they would be most interested in. Similarly, how scientists study meteorites was both placed towards the bottom of the list of interest by both sets of visitors.

Interestingly, visitors to the AMNH tended to be more enthusiastic about topics, consistently rating them as very interesting rather than somewhat interesting compared with visitors to the NHM. It is not known why this might be.

Other differences between the two results suggest that visitors to the NHM are less interested in both Moon rocks and in how scientists study meteorites.

It can be seen that visitors expressed an interest in most of the topics that were suggested and indeed some of the topics had matched visitors' own thinking and expectations of an exhibition on a meteorites theme.

Conclusions

It can be seen from this study that visitors to the NHM do have a great deal of basic knowledge about meteorites and planetary science. They can list and name many of the key areas associated with them.

Visitors tend, however, to have a more limited understanding and a lack of contextual knowledge about the topic.

Visitors appear to be interested in the topics surrounding meteorites, particularly in areas such as what they are made of, where they are from, impact craters and the possibility of life on other planets but the media used to transmit these messages is also very important.

Visitors are less interested in how scientists study meteorites and in the history of meteorite studies. As Museum science is a key area that the Museum is keen to promote this presents a real challenge.

Overall, while visitors do not seem to have a meteorites gallery at the front of their minds while visiting the NHM, it was an idea that did seem potentially interesting to them especially as they started to discuss it.

Areas for further research

This study provides a broad outline of visitor knowledge and needs. More research could be done on many different aspects either with a larger sample size, extending some of the questions covered or more in depth in focus groups.

Perhaps the most useful would be on how the Museum's science could be made more interesting to visitors and more on their understanding rather than knowledge of key ideas and concepts.

Appendix 1

Meteorites Evaluation

Questionnaire

Hello, my name is... and I work here at the museum. We are going to develop a new gallery here at the museum and would like to hear about visitors views and interests on the topic. Would you have 10 or 15 minutes to take part? As a thank-you we are giving people a voucher for the cafe.

1. Who are you visiting with today?

Age	Under 4	5-11	12-16	17-24	25-34	35-44	45-59	Over 60
Males								
Females								

2. I'm going to give you a piece of paper with the word meteorites on it. I'd like you to write down all the words, phrases and ideas that come into your head when you're thinking about the word meteorites.

3. **How familiar are you with these terms?**
[Very familiar, some idea of meaning, not familiar]

Solar System
Supernova
Chondrite
Presolar grain
Star Dust
Meteor shower
Astrology
Meteoritics
Astronomy
Shooting Star
Comet
Asteroid

4. What would you like to know about meteorites? What questions do you have?

5. What would you expect from an exhibition about meteorites at the Natural History Museum?

6. Here are some topics we might include in the hall. When I read the topic, please tell how interested you might be in seeing it in an exhibition.
[Very interested, slightly interested, not interested]

Moon rocks

Meteor impact craters

How scientists study meteorites

How museum scientists study meteorites here at the museum

Origin of the solar system

How planets formed

Meteorites from Mars

Meteorite impacts on earth in the past

Lunar and Martian space missions

History of meteorite studies

Possibility of life on other planets

7. What kinds of technology would you expect to see in an exhibition about meteorites?

8. If there was one thing that would make you visit an exhibition about meteorites, what would it be?

9. Have you visited the museum's current meteorite gallery?

Yes, today

Yes, before today

No

10. Where are you visiting from today?

11. Do you have any special interest or training in science?

Appendix 2

The Earth in Space Primary Space project

By Jonathan Osborne, Pam Wadsworth, Paul Black and John Meadows
Liverpool University Press 1994

“The Primary SPACE project is a classroom based research project which aims to establish

- *The ideas which primary school children have in particular science concept areas.*
- *The possibility of children modifying their ideas as the result of relevant experiences”*

Summary of Chapters 1 and 6

Previous Research – A Review

- Earliest research by Piaget (1929). His interest was the child’s ontology and the understanding of causality.
- Last two decades, interest in children’s alternative framework. Looking at children’s knowledge of the earth, or explanations for the rotation of the earth
- Attraction of research, - how does the child come to construct and use astronomical models (which are counter intuitive).
- A more fundamental question is whether the child’s knowledge can be characterised in terms of elements of fragmented and unrelated knowledge – or do they hold a consistency theory
- Does the child’s knowledge undergo subtle or radical changes?

Children’s explanations

- Previous research used clinical interviews. Piaget asked questions such as “How did the sun begin?” Later, researchers used more specific questions based on models or drawings.
- Piaget suggested three stages development
 1. Artificialism - Sun, moon created by external agents, such as humans or divine beings. Objects may be anthropomorphised.
 2. Origin or natural phenomenon are half natural have artificial.
 3. Origins are unrelated to human action.
- Jones, Lynch & Reesnik (1987) Suggested a 5 stage model, moving through geocentric to heliocentric models, to the correct scientific theory. Evidence suggests a progression of knowledge, and older children were more likely to choose models 4 and 5.

- Baxter (1989) By the age of 15/16 it was still only a minority who gave the scientific explanation for day and night, indicating the strength and tenancy of intuitive explanations.

- Model (of all research stated, combined by author)

Model 1 – Artificialistic (i.e. God made it do that)

Model 2 – Intuitive and naturalistic (i.e. sun goes away)

Model 3 – Stationary earth, sun goes around earth.

Model 4 – Earth goes around the sun once a day

Model 4 – Earth spins on its axis once a day

- Nussbaum, Novak (1976) A seminal, well tested and accepted theory. Established 5 notions about the earth, ranging from flat earth, things falling off the earth in the southern hemisphere, no real concept of down and the scientific explanation.
- Sneider and Pulos (1983) Explored Nussbaum and Novak. Deconstructed their research further, suggesting a link between knowledge of the shape of the earth and the behaviour of gravity. The correct conception of the earth's shape is the antecedent of understanding that objects fall towards the centre of the earth, rather than the obverse.
- Sneider and Pulos – verbal ability was highly significant in understanding the earth concept – at all ages.
- Baxter (1989) Confirmed Nussbaum and Novak. Asked children to draw pictures of the earth, then drawing people on it, then rain coming from the clouds. Many drew vertical rain falling, to the bottom of the page, over a circular earth.

Other astronomical concepts

- Baxter (1989) Students stated the earth cast a shadow on the moon. Maybe a lack of treatment of this topic in many standard syllabi.
- Explanations of the seasons generally very low, so much so only 34% of adults knew that the earth took one year to orbit the sun. One explanation is confusion over the tilt of the axis of the earth, and the nature of elliptical orbit.

The development of children's thinking

- Piaget surmises that development occurs as children realise the common sense causal actions which control astronomical phenomena as opposed to a God, or indeed their parents. Nussbaum and Vosniadou suggest that is in fact a revolutionary shift in the structure of their knowledge, which leads to scientific thinking, and is only possible when intuitive thinking is relinquished.

- Vonsniadou argues that the child's knowledge is based on certain experimental beliefs, and that a radical change is required to obtain the adult concept. The key, she argues is the understanding that the earth is spherical and it is possible to live on such a body without falling off.
- Claxton(1985) Children operate with three sets of concurrent theory. Gut science, Lay or popular science and school science, all used within their context.
- Role of language Jones (1987) Everyday language reflects and reinforces the children's animistic, intuitive thinking.

Pedagogic

Problem that earth is round and rotate is not open direct to direct perception. Until children can relate, development might be difficult for children. Concepts require perception and investigation by children, a complex task for teachers.

Summary of Conclusions

- Children's knowledge of astronomical events is in a process of development across age range.
- Intervention had positive effect – increased level, spread and diversity of knowledge.
- More children give Copernican explanation for day and night with increasing age.
- Children's understanding of distance was essentially weak. Difficulty for young children in grasping scale associated with standard measurements.
- Question whether young children can grasp enormity of solar system in comparison with their own daily world.
- Effects of intervention were positive – suggesting a pedagogical approach does have efficacy in achieving aims.
- Older children have a better understanding of units and interrelationships of time.
- Growth in concept of time is something unitary and holistic rather than an assemblage of independent pieces of knowledge.

- Growth of understanding of the daily trajectory of the sun was not coherent. Connection of length, position of shadows and movement of the sun across the sky not really evident, until upper junior level.
- Lack of correlation between knowledge of sun in summer/winter and length of day reinforces the idea that such knowledge is fragmented and lacks a coherent, unitary picture in the child's mind.
- Evidence suggests that knowledge is figural, seen as independent. The child is unable to operate and generate the abstract relationships that exist.
- Calls into question Vosniadou's assertion, that children are only using one model to explain astronomical phenomena. Some support however for her statement that the key to conceptual understanding is the development of the scientific concept of "down",
- This support is later reduced after the intervention, suggesting that this concept is initially important but weakens with enhanced domain-specific knowledge.

Implications for National Curriculum

- Level 1 (describe the apparent motion of the Sun across the sky.) Only achievable by 31% of upper juniors. Suggests might only be acquired as an isolated fact.
- Level 2 (know that the earth, sun and moon are separate spherical bodies). Easily achievable by all children – suggesting level 1 and 2 should be reversed.
- Level 3 (appearance of the moon and the altitude of the sun change in a regular and predictable manner.) Some evidence that this is attainable. Suggests that only a minority of even upper junior children would be capable of attaining this level.
- Level 4 (explain day and night, the length of the day and year in terms of movement of the Earth and Sun). The data supports the notion that the average child should be capable of attaining such a level.
- Level 5 (describe the motion of the planets). Not explored by research.
- Inconsistency in the difficulty of the levels of attainment and as a developmental scale may be inaccurate.
- Teachers should regard the detail of framework of the national curriculum (for this topic) with a healthy scepticism.

- Research based solely in the classroom. Gains reported are a reflection of what improvement in understanding is important in understanding is achievable in this context.
- Missing from research: Indication of feasibility of pedagogic approach over an extended period of time.
- It is hoped, an emphasis on discussion and reflection would encourage growth of a coherent understanding, rather than assimilation of individual fragments of knowledge.