# Recollections of Exhibits: Stimulated Recall Interviews With Primary School Children About Science Centre Visits

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Abstract

One issue of interest to practitioners and researchers in science centres concerns what meanings visitors are making from their interactions with exhibits and how they make sense of these experiences. The research reported in this study is an exploratory attempt, therefore, to investigate this process by using video clips and still photographs of schoolchildren's interactions with science centre exhibits. These stimuli were used to facilitate reflection about those interactions in follow-up interviews. The data for this study were 63 small group interviews with UK primary school children (129 students, ages 9-11). Interviews were transcribed and then analysed for common themes. The analysis presented here explores how students explain or interpret particular exhibits and the extent to which they were cognitively engaged by the process of observing their interactions with exhibits. The findings show that digital media enable students to revisit their experience and engage them with the content underlying science centre exhibits. There was, however, little difference between the patterns of response stimulated by video as opposed to photographs. It seems that such 'revisitations' of exhibit interactions could serve as a valuable means of developing further students' scientific concepts and exploiting the value for learning from the experience afforded by informal contexts.

Recollections of Exhibits:

Stimulated Recall Interviews With Primary School Children About Science Centre Visits

One issue of interest to both practitioners and researchers in museums and science centres is what meanings visitors are making from their interactions with exhibits and how they make sense of these experiences. Understanding how exhibits[1] are interpreted by visitors could provide guidance for possible improvements and could also highlight ways interactions could be utilised to extend the experience of the visit.

Evidence suggests that interactions with exhibits can have a memorable impact on visitors (Falk et al., 2004; Rennie, 2007; Stevenson, 1991; Tulley & Lucas, 1991). For instance, Stevenson (1991) found that adult and child visitors were able to recall exhibits they had seen or experienced during a science centre visit up to six months after and, in a study conducted by Falk et al. (2004), adult visitors not only remembered the visit itself six months later but could also articulate the impression or impact it had made upon them. Moreover, years of research conducted in science centre settings affirms that visits – whether in family groups or on school trips – are not only remembered but also have the potential to generate both cognitive and affective outcomes (Anderson & Lucas, 1997; Bamberger & Tal, 2007, 2008; Borun et al., 1997; Falk & Dierking, 2000; Hein, 1998; Jarvis & Pell, 2002, 2005; Leinhardt, Crowley, & Knutson, 2002; Orion & Hofstein, 1994). In addition, research has found that such outcomes – particularly cognitive – can be strengthened by reinforcing experiences, such as follow-up activities in the classroom (c.f., Anderson, 1999; Anderson et al., 2000; Farmer & Wott, 1995).

A review of this body of research reflects that much of it has focused traditionally on learning outcomes (DeWitt & Storksdieck, 2008; Falk & Dierking, 1992; Rahm, 2004), but more recently, research has also begun to examine more closely the *processes* of meaning making, with a particular emphasis on conversations that occur during visits (e.g., Ash, 2003; Leinhardt, Crowley, & Knutson, 2002). However, there still seems to be relatively limited work exploring visitors' – especially children's – perspective on exhibits, on how they interpret or explain exhibits and their interactions with them. In one example, Tuckey (1992a) asked children aged 8 to 11 to explain the function and purpose of exhibits during their visits to an interactive science centre. She found that they often drew on their previous knowledge and experience, although the depth and accuracy of their explanations varied considerably. Questionnaires filled out a week later revealed that older children seemed to have some degree of understanding about the underlying principles, while younger children tended to give simpler descriptions of what they had observed (Tuckey, 1992b). However, these data did not reveal what resources or conceptions they brought to bear on understanding or interpreting the exhibits and provided only limited insight into the sense students made of the exhibits. Moreover, this study only investigated children's understanding and memories shortly after the visit, leaving open the question about what the longer-term impressions of the visit might be. Apart from the work of Stevenson (1991) and Falk and his colleagues (2004), most research exploring how visitors, especially children, interpret or explain interactive exhibits has been conducted either during the visit, or shortly after (e.g., Feher & Rice, 1985).

Nevertheless, the field of research on learning in informal settings is not only interested in the sense visitors make of their experiences at the time, but also how their interpretations may change over time. Falk and his colleagues (2004) interviewed visitors to a science centre immediately following their visit as well as four to six months later. Analysis of visitors' responses about what they learned from particular exhibits indicated limited correlations between short-term and long-term outcomes, suggesting that the impact of the visit may shift over time.

The possibility that the impact of a science centre visit, or of exhibit interactions, may change over time, as well as ongoing questions about the nature of longer-term impacts of these experiences, has led us to ask how visitor recollections might be explored in more detail. One promising method involves using the technique of stimulated recall in follow-up interviews. With this method interviewees, such as museum visitors, are shown photos from a setting, such as an exhibition, with the intention of facilitating recall and reflection on the experience. Such techniques have been used in previous research on learning from visits to zoos (Tofield et al., 2003) and science centres (Stevenson, 1991). In his research Stevenson (1991) used photos of exhibits in interviews conducted approximately six months after a visit to an interactive science centre. This study indicated that stimulated recall techniques were effective in prompting recall about the experience, though most of visitors' memories were fairly straightforward accounts of what happened during the exhibit interaction. Memories indicating further reflection were less frequent.

However, trips to science centres are busy, active experiences and any still photograph will fail to capture the dynamic nature of exhibit interactions. Video has a greater capability than static photographs to capture the range and sequence of actions that occur during interactions with science centre exhibits. Therefore, stimulated recall techniques using video may prove more effective than photographs in prompting recall and reflection on these kinds of experiences. Indeed, video has been found to be effective in encouraging adults and children to reflect on their interactions with science centre exhibits immediately after the experience (Falcao & Gilbert, 2005; Stevens & Hall, 1997; Stevens & Martell, 2003). Other researchers have used it as a tool to help secondary school students re-visit and reflect on their learning processes following an amusement park excursion with a physics focus (Anderson &

Nashon, 2007). However, previous studies of science centre visits that have used video have not focused on school trips or have worked with only very small numbers of school children, despite the popularity of science centres as field trip destinations.

Given this evidence suggesting the potential of video to encourage a 're-engagement' with prior experience (Anderson & Nashon, 2007; Falcao & Gilbert, 2005; Stevens & Hall, 1997), the question for us was what potential value did it offer for science centre visits? A particular focus was whether video might offer more promise in encouraging school children to reflect on their interactions with exhibits – that is why they did what they did and/or what they think an exhibit shows – than did the static photos used in previous research (e.g., Stevenson, 1991). Such reflections, in turn, may provide valuable insights into the nature of their experience and into the meanings they are making from their interactions. They may even provide some insight into the processes by which students make meaning – or the resources they bring to bear in interpreting exhibits. Consequently, the research reported here seeks to extend and build on previous work by using video clips of school children's interactions with selected science centre exhibits to facilitate their reflection about those interactions in follow-up interviews – an approach which has not been used elsewhere, other than in a very small pilot study (Falcao & Gilbert, 2005) and then only immediately after a visit. Insight into students' meaning making about exhibits may also potentially highlight new ways to reinforce and enhance learning from these experiences.

It should be noted that the questions explored in this research focus first and foremost on students' cognitive engagement with exhibits and how they make meaning of their experiences. More specifically, this paper will attempt to explore how students explain or interpret particular exhibits and the extent to which they draw on or elaborate concepts in the process. This is not to say that there are not social and affective dimensions to their exhibit interactions and their science centre trip – elements of which are reported here. However, the primary focus of this work was on the potential of video to encourage reflection and cognitive engagement, as this seems to offer more possibilities of supporting and extending conceptual learning afforded by the children's interactions with science centre exhibits.

## Research Design and Data Collection

In order to explore how they interpreted their experiences, video recordings and still photographs were taken of students interacting with selected exhibits during their school trips to a science centre in the United Kingdom, and these photos and video were later used as stimuli to prompt their recall in interviews. The science centre was housed in a dedicated modern, purpose-built building and contained a wide range of exhibits typical of many science centres. The 'target' exhibits included in this study were ones which the researchers could be reasonably certain the students would visit and also permitted filming (i.e., were sufficiently well-lit). Most school trips to this science centre are focused on particular themes (e.g., Forces), which connect to topics in the National Curriculum for England and Wales. During their visits, students are given a paper-based worksheet or 'trail' of five thematically-related exhibits to explore while they are on the exhibit floor, and the 'target' exhibits (where filming took place) were selected from this trail. However, the order in which they visit the exhibits and their timing was under the control of the students, and students had ample time to visit exhibits not on the trail.

Students from upper primary classes (ages 9-11) from five schools participated in the research, representing a convenience sample of schools already scheduled to visit this centre. This was not seen as a limitation as the basic design of this study was exploratory – an attempt to investigate the potential value of such a methodological approach[2]. Exploring new methods is important, as one of the challenges facing the field is to establish good methods for collecting valid and reliable data about what happens during visits to science centres and possible learning outcomes (Osborne & Dillon, 2007). All five schools were publicly-funded and located in suburban areas or small towns. All students for whom consent had been obtained, which was the majority of students in each class, were interviewed following their trips. The interviews were conducted at the schools, using both video clips and still photographs as a prompt to reflection. Both types of stimuli were included to test the possibility that the dynamic medium of video would be more effective than static photographs at stimulating recall and cognitive activation.

Students were interviewed in pairs or groups of three because it was felt that they were likely to be more comfortable being interviewed with a peer than on their own and that the opportunity for peer interaction may stimulate more extensive discourse and elaborated recall. In addition, this research takes a sociocultural perspective on learning, which holds that knowledge is constructed via discourse, in interactions among individuals (Wells, 1999; Wells & Claxton, 2002), and the actions of the individual, the social environment and their interaction all form an inseparable whole. Interviewing students in pairs or threes facilitated social interactions within the context of the interview which, in turn, might have helped students to mutually reconstruct their knowledge and potentially stimulated more extensive recall of their visit. Or, to put it another way, the context of the interview replicated the context of the visit where students explored exhibits predominantly with their peers and possibly enhanced their recall of that experience.

The pairs (or groups of three) in the interviews consisted of peers who had explored the exhibits together. In total, 129 students from the five schools participated in 63 interviews, in which they were shown a combination of video clips and still photographs of themselves at the target exhibits. As shown below, the target exhibits varied with the theme of the visit. In most interviews, students would see a photograph (or photographs) taken at one target exhibit and a video clip (or clips) recorded at another. If there were three target exhibits for that class, the stimulus for the third could be of either type. Occasionally, students saw only video clips or photographs, depending upon what had been recorded during their visit, which was sometimes limited by technical difficulties with the equipment. However, attempts were made to balance roughly whether photos or videos were shown for each exhibit across interviews. The details of the sample, the theme (or focus) of the visit, and the timing of the interviews are summarised in Table 1.

--- Insert Table 1 about here ---

The interview protocols used were developed to explore the cognitive and affective elements of students' interactions with the exhibits, as well as the visit overall. To gain initial insight into students' perspectives on their exhibit interactions, they were first asked questions about what was happening in the clip or photo and how the exhibit 'worked'. To explore cognitive learning outcomes more specifically, students were also asked to discuss what they learned from the experience and what they thought the purpose of the exhibit was (e.g., 'What do you think this exhibit is trying to show you?'). The interviews also addressed affective outcomes, using questions about whether or not students had enjoyed each exhibit they were shown (in a photo or video) and why. Students were not restricted to discussing solely the 'target' exhibits, and during the course of their interviews most students referred to additional exhibits (which did not appear in a video or photo) they had interacted with during their visits. Finally, students were asked to rate how interesting they had found the visit overall and to justify these ratings. The interview protocol is available from the authors.

The qualitative and essentially exploratory nature of this study permitted a degree of flexibility in its design. As Table 1 shows, the participating classes did not have the same 'target' exhibits – these varied depending on the theme of the visit. (A description of the exhibits is found in Appendix 1.) Such a design had the added advantage of allowing the visits to be experienced with a minimum of disruption, in that students were not asked to do anything different from what they would have done normally. Students from two schools were interviewed the week following their visit, but those from the remaining three were interviewed ten to twelve weeks later (after an intervening summer holiday) in order to explore possible differences in recall and reflection over different time periods.

It should also be noted that teachers reported undertaking minimal preparation and no specific follow up to these visits. Given this, it is also unlikely that students were encouraged to discuss or reflect upon the visit prior to the interviews, with the possible exception of students from Chestnut School, whose visit had the ‘Living in Space’ theme (or focus) and occurred at the beginning of a short classroom unit about space.

Coding and Analysis

All interviews with students were transcribed, and a coding schema was developed and refined in an iterative process, in which categories emerged from the data (Lincoln & Guba, 1985). An extensive coding schema was utilised, although the current discussion focuses primarily on findings corresponding to the cognitive dimension of students’ responses. ‘Cognitive’ codes ranged from statements about how the exhibits functioned, to descriptions of the phenomena that were observed, to their understanding of the underlying scientific principles that the exhibits demonstrated. Further sets of codes were developed in order to capture the affective dimensions of students’ interactions with exhibits and responses to the visit overall. Affective codes were generally used to categorise students’ reasons for considering exhibits as enjoyable, fun or interesting, such as the fact that an exhibit was challenging or allowed for hands-on interaction. A list of all code definitions is available from the authors. In addition, transcripts were also coded to indicate whether students were referring to a photo or a video at any given point, so that any differences in their responses based on the type of stimulus could be noted.

The transcripts themselves were coded using the NVIVO software package, which permits a picture of the frequency of code use to emerge. However, while it is of interest to explore what kinds of statements students seemed to be making most frequently when describing their interactions with exhibits, the analyses also note whether particular codes, such as 'science conception', appeared at all in the interview.

## Findings

### *Eliciting Cognitive Response*

The codes used to capture the cognitive dimension of students' reflections, or their cognitive engagement with the content of the video or photo and with the phenomena displayed by these stimuli, were:

- exhibit appearance (visual descriptions of exhibit appearance or 'what it looks like'),
- student action (students' physical interactions with an exhibit),
- observed phenomenon (phenomena that were demonstrated or 'what happened'),
- fact (discrete factual statement, generally a property or process),
- exhibit-focused fact (similar to 'fact' but more closely tied to the exhibit),
- causal (causal explanation),
- science skill (e.g. comparing, classifying) and
- science conception (attempts to use understanding of scientific concept).

A Piagetian analysis would suggest that the order of the scheme represents, roughly, increasing levels of abstraction from that which students could observe visually and experience physically at the exhibit towards more cognitive engagement or reflection on the underlying content of the exhibit. Table 2 summarises the frequency with which these codes were applied to students' interview transcripts.

--- Insert Table 2 about here ---

Because the codes could be applied to statements of varying length (and because of the semi-structured nature of the interviews, in which students talked to varying degrees), statistical analyses of the data are inappropriate. Nevertheless, frequency counts of the data do provide the broad features of their post-hoc reflection. It would seem that the majority of statements made by students when discussing their interactions with exhibits and what they found out from those experiences were fairly straightforward descriptions of the exhibits' appearance or observable features (*exhibit appearance*), of what they did physically with the exhibits (*student action*) and, especially, of the phenomena that were observed (*observed phenomenon*). In addition, this pattern generally held whether video clips or still photographs were used as stimuli (Table 3) and whether interviews were conducted shortly after the visit or following an interval of 10-12 weeks (Table 4).

--- Insert Table 3 about here ---

--- Insert Table 4 about here ---

Thus, as the two samples are similar in the general pattern of codes they produce, further discussion of these findings will draw on all student interviews as the data source in the sections that follow. It is also inappropriate to make a statistical comparison of the number of comments made by students when looking at photos as compared to video clips, as the length of the video clips varied, and students sometimes saw more than a single photo of themselves at an exhibit.

We now turn to discuss the major features emerging from this aspect of the coding, namely statements about what was readily perceptible, statements that indicated further cognitive engagement, and statements utilising students' prior knowledge.

*Readily Perceptible.* As can be observed from the tables, comments about what exhibits looked like (coded *exhibit appearance*) were one of the most frequent kinds of statements and included descriptions such as: 'There's four of those balls' (*Chestnut School, Orbits*) and 'There's this big triangle thing and the air' (*Sugaroak School, Bernoulli Blower*). (For a description of exhibits, please see Appendix 1.)

While the above statements simply named what could be noticed visually about the exhibit itself, other statements (coded *student action*) described what students did physically in interacting with an exhibit – effectively, how to make it 'work'. Examples include: 'You pull a rope, yeah' (*Leaf School, Heave Ho*) and 'We've taken it in turns to spin the thing and then we was pressing the button' (*Redwood School, Hydrogen Rocket*).

Although the above two types of statements (*exhibit appearance* and *student action*) were made quite often by students when discussing exhibits, statements in which students described what they had observed at the exhibit – or what had 'happened' (coded *observed phenomenon*) – tended to appear most frequently in the transcripts, regardless of the type of stimuli used (photo or video), the exhibit being described and whether the interview occurred shortly after the visit or weeks later. In addition, such statements appeared at least once – and generally considerably more often – in every interview conducted. Typical examples were:

> It floats and goes up and down with your hands. It's like you're pushing it, but without touching it. *Sugaroak School, Bernoulli Blower*

> It (the cork) shot up nearly all the way to the top and then came back down. *Chestnut School, Hydrogen Rocket*

> It went for ages. It started doing the circles, and then as it slowed down it began doing the 8 shape. *Redwood School, Orbits*

> When you get it started it goes quite fast, and then when you try and stop it, it's really hard. *Sugaroak School, Kugel*

While such statements are fairly straightforward descriptions of what happened at the exhibits, the fact that it was such features that were recalled indicates that students are going beyond a simple ontological description of its elements and can recall a sequence of events, some of which were not actually visible in the stimuli on which they were commenting.

*Further Cognitive Engagement.* Despite the perceptual nature of most of the statements students made when discussing their interactions with exhibits, some students did spontaneously make statements that seemed to be further removed from what was immediately perceptible. For instance, when asked what he would tell a friend that an exhibit is 'showing', one student replied, 'That air can hold quite light balls in one sort of place' (*Sugaroak School, Bernoulli Blower*). Our view is that this sentence is more generalised in that it describes what air can do – this student having arrived at some sort of conclusion about a property of air, rather than simply stating what he observed while interacting with the exhibit.

In response to a similar question about what he had learned at Orbits, a student from another school responded, 'Balls can't go in holes when it's all bendy' (*Chestnut School*). Whilst such a statement contributes little to understanding the concept and idea underlying the exhibit, it does demonstrate an attempt to construct a generalised explanation and to go beyond the phenomenon itself. Speaking about the Bubble Race exhibit, another student explained that he found out that ‘Air bubbles move faster through thinner liquids than thicker liquids’ (*Leaf School, Bubble Race*). And similar types of statements were made about other exhibits, such as: ‘Different pulleys can make it easier or harder to pull up six kilograms’ (*Leaf School, Heave Ho*) and ‘Water can make things easier to push’ (*Sugaroak School, Kugel*).

The above statements suggest that students were attempting to extract the underlying properties or characteristics of balls and surfaces, of air bubbles and liquids, and of pulleys and water. In all cases, this is a process that requires the ability to see beyond the descriptive and a willingness to construct models of physical systems – features which suggest a greater degree of cognitive engagement and reflection on their experience than just descriptive accounts of what the exhibit is or what it does. As Table 5 shows, statements coded as *Fact* or *Exhibit-focused fact*, while certainly less frequent than descriptions of the phenomena that were observed, appeared at least once in 90% (57 of 63) of the interviews, suggesting that stimulated recall techniques can prompt this greater level of generalisation or distance from what is immediately perceptible. That such statements were elicited also highlights the importance of scaffolding in order to make the most of these types of experiences. Unless students are scaffolded to transcend the simple ontological questions of what the exhibit is or what it does, to ask the causal question of how it works or the more general question of what it shows, it is doubtful if the full educational experience of the interaction – and the visit – will be exploited.

--- Insert Table 5 about here ---

Cognitive engagement with what can be observed at an exhibit is also suggested by statements in which students attempted to provide a *causal explanation* for what they see. For instance, one student noted that the Kugel (a big granite ball resting on a thin film of water) was very hard to stop once it was spinning. In describing what happened, he explained that it was the water making it hard to stop 'because it's slippery.' (*Sugaroak School*). A classmate explained the same phenomenon by saying, 'You couldn't stop it because the water was underneath and still pushing it' (*Sugaroak School).*

Thus, revisiting the experience in an interview has stimulated the construction of an explanation, albeit scientifically incorrect. Likewise, students from another school tried to explain why one of the bags in Heave Ho felt heavier:

S1: That one's easiest.

S2: Because it has more pulley-things. (*Leaf School*)

While the above statement does not articulate *how* pulleys make something more difficult or easier to pull, it does indicate an attempt to describe the cause of what was observed. Other students provided more detailed causal explanations of observed phenomena, although these were not always correct. In the following excerpt, a student attempted to explain why the cork goes up in the Hydrogen Rocket exhibit:

> I think it's like air pressure. And as it builds up inside that chamber then it… it kind of sucks up all the air pressure. And then it lets it out into the rocket shaped thing, and then that pushes up a cork and makes it go up. (*Redwood School)*

A student from another school provided a different, also incorrect, explanation: 'Water – it got bubbles into it a bit and they pushed it – and it would go really higher' *(Chestnut School).*

Although statements such as these were not as frequent as the observations themselves, that 12% of cognitive statements did reflect attempts to provide some sort of causal explanation for an observed phenomenon would seem to be noteworthy. The appearance of such statements shows the potential that re-visiting exhibit interactions afford as a means of encouraging students to think more deeply about what has been observed and to begin to construct explanatory models – something which is central to the nature of science itself. Moreover, students made this kind of statement in 94% (59 of 63) of interviews and such statements occurred in the context of interviews which primarily attempted to elicit what students might remember about their science centre visits. It remains an open question how much better teaching and learning experiences which attempted specifically to exploit the potential of such nascent memories for learning science might be.

*Using Prior Knowledge.* Finally, some students not only tried to provide causal explanations for what they observed, but went a stage further by attempting to bring their existing science conceptions or understandings to bear as they tried to interpret, explain, or make sense of interactive exhibits. For instance, in describing what the Bernoulli Blower was attempting to show, one student explained, 'It's, like, overpowering, well, it's not overpowering gravity, but it equals gravity. So, it's the up-thrust, it was gravity, so it lets it float.' He then went on to state: 'You can equal, like, the force of gravity with another force – usually you can't just make a ball float in the air' (*Leaf School*). This student did have some difficulty in articulating his interpretation of the exhibit (which is not entirely accurate). Nevertheless, he attempted to apply the scientific concepts of force and gravity (or his understanding of them) as he tried to explain what he had observed.

Another student also referred to gravity as she attempted to explain Heave Ho: 'I think probably what I learnt from it was that it was probably showing us that probably the heavier a thing is, the greater gravity pulls down on it' (*Leaf School*). In this case the student missed the point of the exhibit and may not have noticed the pulleys at all. However, she had noticed that different bags seemed to weigh different amounts (in that some were easier or harder to lift) and attempted to draw upon a familiar science concept she connected with weight – gravity. Later statements reflected that her understanding of gravity was not as sophisticated or accurate as the above comment might suggest, but the important point here is that it demonstrates an attempt to utilise her science knowledge to explain what she has observed.

In describing what they learned from their interactions with the exhibit Kugel, students from another school also referred to science concepts:

S1: Trying to stop it, it's like friction with the water and the ball in your hands.

S2: It's like water pressure a bit, but not. Well, you're trying to push it and the water's moving it… making you not, cos it's getting slippery. (*Sugaroak School*)

The second comment, in particular, illustrates the student drawing on his understanding of a range of science concepts, as he struggled to find the term that would adequately explain what he had observed.

In another instance, two students refer to gravity, as well as thrust, in attempting to explain Hydrogen Rocket:

S1: It's like the rocket going up in space.

S2: Yeah, because when it goes up, it's really hard because you need all them rocket fuel and all that to burn and the thrust to push it up.

S1: Because the thrust pushes the rocket up. And when it gets up…

S2: Well, it sucks it down again.

S1: Yeah, because of the gravity. (*Chestnut School*)



Although such statements did not appear frequently in the transcripts, that they occurred at all is of interest because they highlight the way in which students were attempting to make sense of their experiences in the visit by drawing on their existing understanding of scientific concepts. That these '*science conception*' statements appeared at least once in 83% (52 of 63) of the interviews again indicates the potential of utilising stimulated recall in interviews to encourage reflection on underlying science principles. From a constructivist perspective (Hein, 1995; Osborne & Wittrock, 1985), such a finding is also not surprising as it illustrates children attempting to make sense of the unfamiliar in terms of their pre-existing concepts. It also reinforces the importance of science centres utilising students' common conceptual frameworks – that is, the ideas they are likely to be familiar with from school and everyday life – as a starting point from which they can help students develop their knowledge and understanding from their visit experiences.

We do not suggest that students would have spontaneously reflected on these exhibits, either during the visit or subsequently, nor that they would utilise their existing science understandings without being prompted. Nevertheless, the interviews do provide evidence, consistent with previous research (e.g., Stevens & Hall, 1997; Stevens & Martell, 2003) that interactions with science centre exhibits can provide opportunities for reflection and deeper engagement with science concepts and processes after the visit itself, even after considerable delay. Such reflection and engagement can serve as building blocks for the development of future understandings. Moreover, that using video (or photos) to re-visit these experiences following a school trip can be cognitively demanding suggests that there is educational value to incorporating such media in follow-up activities, a practice that teachers may find relatively easy to implement, given how many take photos or even video during school trips (Kisiel, 2006).

*Students' Views of the Function and Purpose of Exhibits*. The interview data not only provided evidence of the way in which re-visiting their exhibit interactions could engage students with underlying science content, but also showed that students seemed to view the visit as a 'learning experience' – they were often able to articulate answers to questions about what they thought particular exhibits were supposed to show. Their interpretations were not always correct, indeed rarely so, but students clearly seemed to appreciate – and expect – that the exhibits they encountered had a purpose, generally related to science. For instance, when asked about the purpose of Hydrogen Rocket, students responded:

S1: It's to show how high it can go.

S2: It's showing the power and the electricity and mixing the liquids, so like science, all part of science. (*Chestnut School*)

That students did connect these experiences with learning science is not only reflected by the purposes they ascribed to the exhibits and their attempts to utilise existing science understandings to interpret observed phenomena, but is also suggested by their frequent use of science terminology (such as *gravity*, *friction*, and *pressure*). Nearly all students used such terms as they talked about exhibits they had encountered during their visits, with these terms appearing in 87% of interviews. Some students, albeit fewer, even described how they used science skills – such as fair testing – in their exhibit interactions. For instance, in discussing what he had done at the Bubble Race exhibit, one student said, 'But to make it a fair test, you have to wait until they [bubbles] were all equal at the bottom' (*Leaf School, Bubble Race*). Another reported, 'I did a big spin. And I did it twice to make the test fair. Because, like, if you did it once and you didn't exactly get the right answer, do it again to make it get the right answer, if it is the right answer' (*Leaf School, Bubble Race).*

Nevertheless, although students at various times used scientific terminology, referred to science process skills and drew upon their prior science knowledge in the interviews, they rarely made connections explicitly to what they had learned in school.

*Stimulus Type and Interview Timing.* As Table 3 reflects, the patterns of statements students made when discussing their interactions with exhibits were broadly similar, with a predominance of observational statements, whether presented with a photograph or a video as a stimulus for recall. These general patterns were also found regardless of when the interview was conducted (Table 4). That is, most statements were descriptions of aspects of the exhibit itself, what students did with it or the phenomena that could be observed. However, some students were able to speak more generally about properties, and could provide causal explanations for some of the phenomena they observed, sometimes even utilising their existing science understandings in doing so. What is of interest is that this overall pattern seemed to hold regardless of stimulus type or of the timing of the interview. Why might this be? Is it possible that 3 months, even with an intervening summer holiday, was simply not long enough for differences to appear? Or is it a fact that the dynamic nature of the video makes little difference as a stimulus to recall when one is able to recall the whole episode and mentally replay it in the mind? If so, it would suggest that the impact of the visit had been significant, creating a memory that was sustained even several months after the visit – and a memory which only required a small prompt to bring it to the fore again.

Although the general patterns of statements reflecting the cognitive dimension of the visit were similar across stimulus type and interview timing, students seemed to refer to their conversations with other students more often when looking at a video rather than a photo. This could be because the element that videos do capture is the dynamic interaction between students and the exhibit where conversation is often central. Hence the video may stimulate recall of conversation which a still photograph may fail to do. However, it should be noted that the sound was not of particularly high quality and students' comments did not always directly refer to talk heard in the recording.

*Differences Among Exhibits?* The distribution of the types of statements was also generally consistent across the various types of exhibits in this study. Table 6 reflects that in discussing any exhibit students tended to describe the phenomena that they observed. They provided more generalised comments and causal explanations less frequently, but such statements – as well as those in which existing science knowledge was brought to bear – were made in reference to all six exhibits used in this research.

--- Insert Table 6 about here ---

One difference worth mentioning is that, when discussing the Bubble Race exhibit, there were fewer instances of students bringing science concepts to bear, but they often referred to the science process skill of fair testing. The nature of the exhibit – with a clear comparison to be made and an intuitive way to repeat the test or comparison – seems likely to have contributed to this difference.

The only other difference found in the data is that a smaller proportion of students' cognitive statements for Orbits were causal explanations, compared with cognitive statements they were making about the other exhibits. That the exhibit failed to stimulate causal explanation may also be why students frequently described Orbits as ‘just a game’. This would suggest that it is erroneous to think that exhibits can speak for themselves with minimal or no interpretation. Indeed many science centre exhibits are accompanied by either no or very limited explanatory text. In addition, centres are often not able to provide sufficient staff to facilitate interactions with exhibits. Visitors are often simply left to construct, for themselves, an explanation. The result is an emphasis on the phenomenon as opposed to the explanatory theory it illustrates. Yet it is theories of science that are the ‘crowning glory of science’ (Harré, 1984). While it can be debated as to whether increasing visitors’ understanding of canonical theoretical explanations of phenomena is an appropriate or reasonable goal for science centre visits, the data from this research reinforce that the goal of supporting any development of science concepts is unlikely to be achieved without scaffolding, either during or after the visit.

*The Visit as an Affective Experience*

While the findings described above suggest that the visit was memorable and offered potential as a building block on which further understanding could be scaffolded, the trips were also positive, enjoyable experiences for the students. When asked to rate how interesting they had found the visit, 83% (107 students) ranked it as ‘very interesting’ and 15% (20 students) as ‘interesting’. (The remaining two students claimed it was ‘neither interesting nor boring’). Similar patterns were seen whether students were interviewed shortly after the visit or later, although a greater proportion of students considered it to be ‘very interesting’ immediately after the visit (90%) compared with those who were interviewed 10-12 weeks later (76%). Although the reason for this difference is unclear, it may be that after more time had elapsed, the memory had faded somewhat and muted the students’ recollection of how interesting the trip had been.

Students were also asked to justify their ratings, and gave a variety of reasons. Some students found their visit to be interesting because it offered multiple opportunities for exploration and interaction with exhibits. According to one, ‘I never knew you could do so much stuff there, and do experiments and stuff’ (*Leaf School*). Others considered it to have been very interesting because they felt they had learned something. For instance, one student claimed, ‘You learnt loads of things on the different exhibitions’ (*Chestnut School*).

Some students went further, describing the experience as something that had combined both fun and learning. For example, ‘It was interesting because you’re having fun and still learning science at the same time. So I quite liked it’ (*Leaf School*).

Students also frequently contrasted their experience of the visit with school, particularly their experience of science in school.

S1: Cos we went to Techniquest it’s kind of changed the way we think about science.

S2: So then, so next time we do about air, we’re going to think ‘Oh I remember from Techniquest we did that.’

S1: But then it will seem boring because we’ll have memories of Techniquest being really fun, and then you go into the lesson and you’re like, ‘Oh this is really boring.’ (*Sugaroak School*)

> It makes science fun and that doesn’t usually happen a lot. Because at school everybody thinks science is boring, but it’s not there. (*Redwood School*)

In addition to providing reasons why they had found the visit to be interesting, students were also asked to select which exhibit they had found to be most fun and which had been most interesting for them and why. Although no one exhibit was chosen consistently, the reasons students gave for choosing the exhibits they had were quite consistent. Students frequently found exhibits to be fun or interesting because they allowed hands-on interaction. As one put it, ‘They’re all interesting ‘cos you pull on one and then the other one you like chuck it in the air and it floats. That one you’ve got to spin it around’ (*Sugaroak School, about Heave Ho, Bernoulli Blower and Kugel, respectively*). Similarly, another said, ‘We were, like, turning the handle…’ (*Maple School, Hydrogen Rocket*).

Students also spoke positively of exhibits which offered multiple opportunities for exploration or interaction. For instance, the Kugel was liked because ‘you have loads of different ways and then you just spin it in loads of ways’ (*Sugaroak School*)

What this suggests is that the opportunity to manipulate the material world remains a key point of engagement for individuals – particularly in a society where such opportunities are diminishing (Greenfield, 2009; Tapscott, 2009). When manipulating an exhibit, students have an identifiable goal of comprehending how it works and possibly, as well, the explanatory rules that govern its behaviour. Thus the exhibit poses a challenge permitting the visitor to become engaged. In addition, interactive exhibits offer a sense of control – something which the normal formal educational experience rarely affords (Paris, 1998).

Not surprisingly then, exhibits which did not seem interactive or controllable to students were perceived as less fun or interesting. One student remarked, ‘That one, you can’t touch the water inside’ (*Maple School, Hydrogen Rocket*). Likewise, those that offered only limited possibilities for exploration were viewed negatively: ‘The rocket one, all you do is turn the handle’ (*Maple School, Hydrogen Rocket*).

However, a feature of exhibits that did engage many of the students was that they offered an opportunity to collaborate with others. A different student praised the same exhibit by saying, ‘You had to help each other and everything’ (*Redwood School, Hydrogen Rocket*).

In addition, the novelty of exhibits would also seem to contribute to engagement as students were intrigued by, or enjoyed, exhibits that were novel or contrasted with their previous experiences. In the words of one student, 'But with the blower one I found really interesting because I've never seen something like that' (*Leaf School, Bernoulli Blower*). Although novelty can detract from learning (Anderson & Lucas, 1997; Falk & Balling, 1982; Falk, Martin, & Balling, 1978), statements such as the previous suggest that novelty can also make experiences memorable.

Many students recounted the phenomenon that could be observed at an exhibit as justification for selecting it as fun or interesting, implying that the phenomenon itself was somehow of intrinsic interest (for reasons not entirely clear), while some students would go further to explain that its value lay in the fact that they had found out or learned something: 'It was very fun finding out that it [the bubble] would move faster through the oil' (*Leaf School, Bubble Race*). Some students also stated that they appreciated exhibits which were perceived as cognitively challenging: 'It's like a puzzle, which was quite hard' *(Sugaroak School, Kugel)*. Thus, these data suggest that some, and possibly all, students would value a visit which, whilst permitting 'hands-on' manipulation, would also offer them the opportunity to learn.

Notably, however, students' perceptions of which exhibits were most fun or interesting varied and no distinctive pattern of engagement emerged. That is, one student may have preferred a particular exhibit because it offered an opportunity to learn, while another might have found it fun because it offered multiple opportunities for exploration. And yet another student may have disliked the same exhibit because she found it offered a limited repertoire of activities. Centres which offer a wider diversity of exhibits and potential activities are, therefore, more likely to engage a wider set of young students.

## Discussion

Looking across types of stimuli (photos and video), interview timing (shortly after the science centre visit or weeks later) and exhibit types, the interview data suggest that their visits provided highly memorable experiences for students. The way they interpreted or described the stimuli frequently went beyond what was observable in the photo or video. Students' statements ranged from fairly elaborate descriptions of the observable phenomena at the exhibits, to more generalised and even causal explanations of these phenomena or the science that students believed underlay the phenomena. Moreover, the data also demonstrate that these interactions with exhibits were positive, enjoyable, often social experiences for the students, and experiences from which they expected to learn.

Indeed, such an expectation may partially account for why students attempted to use their understandings of science to explain the exhibits. For, if they believed the trip to the science centre had to do with 'learning science', it is perhaps not surprising that students concluded that the exhibits themselves were meant to demonstrate something about science, and consequently, attempted to apply their understanding of science in interpreting their observations. Such expectations also reinforce recommendations made by researchers (e.g., Griffin & Symington, 1997) that teachers should emphasise to students that a visit to a science centre does have to do with learning science and that they should expect exhibits to demonstrate science concepts and principles.

That students participating in this research also found the experience of visiting a science centre to be enjoyable means that such visits provide an opportunity which can be exploited by teachers for student learning. Put differently, that a visit is so memorable, engaging, enjoyable and considered to be connected to science highlights the opportunities afforded by 're-visiting' the experience to build students' science knowledge. However, although students often tried to bring their science understandings to bear in interpreting the exhibits, they were often incorrect, confused or inappropriate. Hence, such opportunities will only really be exploited by providing an occasion after the visit to reflect and re-engage with the phenomenon when their understanding can be developed and scaffolded.

For instance, the following conversation occurred between two students (and the interviewer) while looking at a photograph of themselves at the Heave Ho exhibit:

I: So, what can you tell me about that one and what you were doing with it?

S1: They're all the same. It's weird cos I think they're all the same kilograms, but they all feel heavier.

I: Mmm. So they feel…

S2: They're different.

I: Yeah. They feel different.

S1: Maybe it's because, like, you've tried one which is the lightest, then you go on to another and pull it again and lift your arms.

S2: Well, it might be something to do with the actual thing

S1: The rope's heavier.

S2: There are those things that you can pull engines up easy.

S1: Yeah, and the rope might have been heavier to pull and, like

S2: It might've been a longer rope and it might have been a bit more heavier. (*Sugaroak School*)

In the above excerpt it is apparent that the students noticed that the sensation of lifting the sacks suggested that they contained different weights, although they were labelled with the same weight. They offer two explanations of what they have observed – one concerning muscle fatigue and the other the weight of the rope. The second student also notices the pulleys (‘these things that you can pull engines up easy’). Unless student thinking is then challenged, it is unlikely that their scientific understanding will be developed further. In this case, the salient feature is that the ease of lifting is correlated with the number of pulleys. Once this factor has been identified as the significant observation, the issue becomes one of how the numbers of pulleys account for the observed difference in heaviness among the sacks.

## Conclusions and Implications

In summary, the data from this exploratory study suggest that students were cognitively and affectively engaged by the process of reflecting on their interactions with science centre visits. From a cognitive standpoint, most of the students’ statements were descriptive. However, their comments did extend to attempts to provide causal explanations and to use their science understandings to explain the phenomena they observed. In the interviews students also reflected on the affective dimension of their visit, discussing what made particular exhibits – and the visit as a whole – fun and interesting. Perhaps not surprisingly, such factors included students’ perceptions that exhibits were interactive or hands-on, were novel, offered multiple opportunities for exploration, allowed collaboration and combined fun and learning.

It is important to recall that these reflections on the visit did not occur in a vacuum. They were stimulated by the photos and video clips and were elicited by interviewer questions. Thus, the findings would seem to highlight the role of mediation in encouraging these kinds of reflections which may, in turn, help students get the most out of their interactions with exhibits as it is such mediation that may help scaffold students’ developing understandings of science concepts.

It can be challenging to provide such mediation during a science centre visit. Anecdotally, the visits which formed part of the current research were not unlike what Paris (1998) describes:

Most of them raced from one exhibit to the next, spending less time than a minute at most and less than 20 seconds at many. They turned handles, pushed buttons, pulled ropes, and sped to the next exhibit. Their motivation displayed free choice but their behavior seemed directed at 'making things happen' or, at best, understanding *how* to make each exhibit work rather than *why* it operated as it did. Some may call this a performance goal; others may call it a procedural, as opposed to conceptual orientation to exhibits. Still others might say it is an expected response pattern when you turn loose a class of students with limited time to see many interesting exhibits. Regardless of the reason, all three factors diverted children's motivation from understanding, and exploring, and learning about the exhibits (p.23).

Such behaviour is likely to be attributable, at least in part, to the novelty of the setting. A challenge for science centres is to balance the varying impacts of novelty. While science centres often want to maximise the (cognitive) learning potential of visits, this is unlikely to occur if students fail to go beyond the experience of simply sampling one exhibit after another. Many centres also want to support the affective engagement elicited by the novelty of the experience. Mediation, we would contend, is essential to achieving this balance. Whilst students need to experience the excitement of freely exploring novel exhibits, they also need help to identify the salient features of those exhibits. Undoubtedly, mediation can occur during the visit and some students' statements reflected this possibility:

> When you have people with you, you can talk about what weights are which. And when you just go on your own, you just pick it up and drop it, then pick it up and drop it and then there's no one to say 'What did you find out about it?' (*Sugaroak School, Heave Ho*)

> She [the teacher] was asking the question of which one would be travelling the fastest and she was saying that, well, the motor oil was, cos it's a lot thicker liquid, that the bubble would travel slower. (*Leaf School, Bubble Race*)

Without the direction given by the teacher in the statement above, students may easily miss the important scientific and technological aspects illustrated by the exhibit. Nevertheless, an important implication of this study is that such mediation can *also* occur away from the exhibit itself, when viewing video recorded at the exhibit. That this should be the case is not surprising, given previous research which used video recordings to stimulate visitors' reflection in informal learning environments (Stevens & Hall, 1997; Stevens & Martell, 2003). This study is significant, however, in showing the kinds of reflection that can be prompted by such stimuli away from the science centre, even months after the visit. Photographs and video thus offer a means by which can students can engage with both the content and processes underlying exhibits in a way that could support or scaffold the further development of science concepts, particularly when mediated by a teacher. Moreover, in discussing video clips and photos, students may make their interpretations and understandings more explicit – and as such, these reflections can in turn be used as a tool to construct meaning from their experience.

To extend the learning potential of the visit, science centres could even make clips of exhibit interactions available on their web sites. Alternatively, modern mobile phones permit students to readily collect short clips of phenomena or exhibits they consider significant, and many clips are publically available on YouTube. Informal conversations with teachers whose classes participated in the current study indicated that such clips (even of other individuals) would be a welcome and useful classroom resource to use either as an advance organiser to help point out key features to observe or as a prompt to further discussion after the visit. The data from the interviews conducted for this study indicate the kind of discussion that such stimuli can generate. Moreover, photographs or video will enable students to re-visit a positive experience, as well as supporting the kind of engagement and reflection useful in building further science concepts. Such actions could, in turn, help maximise the potential of science centre visits for learning. If the boundary between learning in formal and informal contexts is to be dissolved, it is essential for museum educators and teachers to make use of such media which will enable the value of the experience offered by the science centres and experiences outside the classroom to be exploited as an educational resource for learning inside the classroom. The findings of this study have, we hope, suggested one step to achieving this goal.

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# Appendix 1: Exhibits

**Bernoulli Blower:** A stream of air is blown at an upwards angle out of a pyramid-shaped base. The air flows over the top of a beach ball, creating lift and causing the beach ball to float or hover in mid-air. (The ball must initially be held in the air stream and then released, in order for the effect to be seen.)

**Bubble Race:** A wheel approximately three feet in diameter contains five tubes, each with a different-coloured liquid. The wheel is mounted against a wall and can be rotated or spun. When spun, air bubbles travel through the liquid from the bottom to the top of the tubes, with their speed dependent on the viscosity of the liquid (water, motor oil, bubble bath, etc).

**Heave Ho:** Three sacks of identical weight (6 kg) are suspended with rope from a metal frame, but each rope is held by varying numbers of pulleys (one, two, or three) at the top. The sacks are opaque, and each has '6 kg' printed on one side. Depending on the number of pulleys, each sack is easier or more difficult to lift, when the rope is pulled. The exhibit is intended to demonstrate the mechanical advantage afforded by varying numbers of pulleys.

**Hydrogen Rocket:** Visitors spin a handle, causing gases to mix inside of a clear container. Consequently, a small explosion (produced by the gases and accompanied by a 'pop') powers a cork up a line, after which it falls back to its starting point.

**Kugel:** A large granite ball, weighing one half ton, is covered in water, which enables it to be rotated (when pushed) on a cement base.

**Orbits:** Four golf ball-size balls can be spun or thrown across a surface. The exhibit itself has an oval shape, but the surface slopes towards two holes. The shape of the surface causes each ball to travel in a figure-8 shape, until eventually it spins around a single hole and drops in.

Footnotes

[1]In this paper the term 'exhibit' is used to refer to a single interactive.

[2] A much shorter description of this work based on a few initial analyses of a subset of the data and some of the insights emerging have previously appeared in DeWitt (2008)

Table 1

*Information about classes and visits*

| School | Year group | No. students | Visit theme | Target exhibits | Interview timing |
|---|---|---|---|---|---|
| Leaf | Year 6 (age 10-11) | 41 (19 interviews) | Investigate | Bernoulli Blower<br>Heave Ho<br>Bubble Race | Following week |
| Redwood | Year 6 | 17 (8 interviews) | Living in Space | Orbits<br>Hydrogen Rocket | Following week |
| Chestnut | Year 5 (age 9-10) | 25 (13 interviews) | Living in Space | Orbits<br>Hydrogen Rocket | 10-12 weeks later |
| Maple* | Year 5 | 6 (3 interviews) | Living in Space | Orbits<br>Hydrogen Rocket | 10-12 weeks later |
| Sugaroak | Year 5 | 40 (20 interviews) | Forces | Bernoulli Blower<br>Heave Ho<br>Kugel | 10-12 weeks later |

*Only six students from this school visited the science centre when scheduled, due to a last-minute change in scheduling for most of the students in the class (involving a sports day).

Table 2

*Types of student statements (all interviews)*

| Code | Frequency of use |
|---|---|
| Exhibit appearance | 17% (390 statements) |
| Student action | 18% (418) |
| Observed phenomenon | 31% (720) |
| Fact | 5% (116) |
| Exhibit-focused fact | 7% (157) |
| Causal | 12% (275) |
| Science skill | 3% (79) |
| Science conception | 7% (163) |

Table 3

*Types of statements made by stimulus type*

| Code | Video clip | Still photograph |
|---|---|---|
| Exhibit appearance | 16% (176) | 15% (121 statements) |
| Student action | 18% (202) | 20% (163) |
| Observed phenomenon | 30% (326) | 30% (240) |
| Fact | 4% (40) | 5% (38) |
| Exhibit-focused fact | 7% (79) | 7% (57) |
| Causal | 13% (133) | 13% (104) |
| Science skill | 4% (47) | 3% (25) |
| Science conception | 8% (82) | 7% (58) |

N.B., The number of statements represented in this table is smaller than in Table 4. This is because Tables 2 and 4 reflect all of students' statements receiving a cognitive code, including those not made in response to any stimulus (photo or video).

Table 4

*Types of statements by timing of interview*

| Code | Shortly after visit | Delayed |
|---|---|---|
| Exhibit appearance | 13% (102) | 19% (288) |
| Student action | 16% (127) | 19% (291) |
| Observed phenomenon | 29% (228) | 32% (492) |
| Fact | 8% (63) | 4% (53) |
| Exhibit-focused fact | 6% (44) | 7% (113) |
| Causal | 14% (105) | 12% (170) |
| Science skill | 5% (38) | 3% (41) |
| Science conception | 10% (77) | 6% (86) |

Table 5

*Interviews in which types of statements appeared at least once*

| Code | Interviews |
|---|---|
| Exhibit appearance | 95% (60 of 63 interviews) |
| Student action | 100% (63) |
| Observed phenomenon | 100% (63) |
| Fact | 68% (43) |
| Exhibit-focused fact | 76% (48) |
| Fact AND/OR exhibit-focused fact | 90% (57) |
| Causal | 94% (59) |
| Science skill | 54% (34) |
| Science conception | 83% (52) |

Table 6

*Types of statements by exhibit type*

| Code | Bernoulli Blower | Bubble Race | Heave Ho | Kugel | Orbits | Hydrogen Rocket |
|---|---|---|---|---|---|---|
| Exhibit appearance | 8% | 11% | 21% | 18% | 13% | 20% |
| Student action | 15% | 16% | 18% | 20% | 22% | 20% |
| Observed phenomenon | 33% | 22% | 24% | 31% | 38% | 28% |
| Fact | 6% | 13% | 6% | 3% | 3% | 2% |
| Exhibit-focused fact | 7% | 15% | 5% | 8% | 7% | 7% |
| Causal | 17% | 13% | 12% | 12% | 8% | 13% |
| Science skill | 4% | 8% | 6% | 1% | 2% | 3% |
| Science conception | 10% | 2% | 8% | 7% | 8% | 8% |
| Total number of statements | 426 | 134 | 342 | 302 | 320 | 486 |