Evaluating the Design of Interactive Exhibits

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Evaluation in science and technology centres: The background

All science centres have a mission statement, which includes some kind of intent to improve the public appreciation, understanding or awareness of science. Questacon – The National Science and Technology Centre in Australia aspires to be a Centre that "raises national awareness, fosters understanding and instills positive attitudes to science and technology". Aims such as these are, however, impossible to evaluate in a quantitative way, since such evaluation implies exhaustive pre-visit and post-visit testing both of visitors and non-visitors.

Worldwide evaluative studies of science centres have therefore focused mainly on small-scale evaluations of specific aspects of exhibits and exhibitions. Exit surveys (e.g. Groves, 1999), random visitor questionnaires and so on have served to provide some information about affective outcomes but these reports have been used mainly 'in-house', to improve or modify the exhibition itself.

Interactive science centres and museums are, however, increasingly being recognised as centres of informal science learning (e.g. Crane, Nicholson, Chen and Bitgood, 1994; Falk and Dierking, 1992; Falk, Koran and Dierking, 1986; Gilbert, Stocklmayer and Garnett, 1999; Griffin and Symington, 1999; Rennie, 1999; Rennie and McClafferty, 1996; Stevenson, 1991). The influence of "hands-on" activity has been examined in the context of cognitive and affective outcomes through a number of studies (see Griffin and Symington, 1999). These studies have generally sought to describe learning outcomes in terms of the perceived aims of the exhibit, especially in relation to the scientific principles being presented for investigation. The studies have therefore tended to focus largely on more formal outcomes, with the result that visitors have been found to have little recall of the science and, in many cases, little understanding of the principles underlying the exhibit.

A long-term study at Questacon has explored the way in which visitors interact with exhibits in an attempt to explain why engagement with exhibits occurs and what changes occur to the mental models held by visitors (Gilbert, Stocklmayer and Garnett, 1999). To date, with a few distinguished exceptions (e.g.McClafferty and Rennie, 1997; Stevenson, 1991), relatively little psychology-based enquiry has occurred into the nature of the 'interactivity' that takes place, that is into the sensation of learning that visitors experience as they use interactive exhibits. We have chosen to examine this interactivity from the perspective of the visitor rather than that of the science centre.

Turney (1996) suggests that only when people see an opportunity to participate in the conduct of science or, more realistically, to take an active role in learning what science can achieve, will they begin to understand science in the more traditional sense. The Questacon study has emphasised that this active engagement in science (and technology, for the two are intimately entwined in the modern world) is facilitated by interactive exhibits.

The study has established that the learning which occurs is related to the visitor's prior awareness of science and that the exhibit is always interpreted in terms of this awareness. Cognitive and affective outcomes are governed largely by the mental model of the visitor before the interaction commenced, since this essentially dictates the nature and level of the interaction (Gilbert, Stocklmayer and Garnett, 1999, Stocklmayer and Gilbert, in press).

For some exhibits, however, the cognitive and affective outcomes appeared particularly unrelated or only loosely related to the intent of the designer. In these cases, the scientific principles underlying the exhibit usually were presented in a complex analogical form. It seemed likely that the nature of the analogy was contributing to the nature of the outcomes. This has significance for exhibit designers, in that they may be able to predict the likely cognitive outcomes of an interaction in terms of the analogy chosen to represent the underlying science (Gilbert and Stocklmayer, in preparation).

Models in science

An interactive exhibit may be considered as a *model*. Models play a major role in the intellectual and social conduct of science and are substantive outcomes of those activities. A model may be defined in general as a representation of an idea, object, event, system, or process (Gilbert and Stocklmayer, 1997). A model is formed by considering that which is to be represented (the target) analogically in the light of the entities and structures of something which it is thought to be like (the source). The target itself may be termed a 'consensus' model in terms of the following definition (Gilbert, Stocklmayer & Garnett, 1999, p.17):

> "A consensus model is an expressed model which has been subjected to testing by any social grouping, especially by the academic community

associated with a given subject, and which has been socially agreed by at least some members of the group as having merit for the time being."

The underlying ideas – the target – behind an interactive exhibit are most likely to be related strongly to such a consensus model, whether it be a traditional science concept or process or an emerging 'issue' in science.

The exhibit itself, however, is not a consensus model but is a representation of it, designed to facilitate understanding. It is, therefore, a 'teaching' model:

> "A teaching model is a specially constructed expressed model used to aid the understanding of a given consensus model." (Gilbert and Stocklmayer, 1999, p.17).

It is the closeness of the teaching model to the *prior experience* of the visitor which determines the initial engagement, the nature of the experience and the 'success' of the interaction. It is the close or distant *relationship* between teaching and consensus models (the exhibit and the underlying principles) which to some extent determines the overall cognitive outcomes. (Gilbert and Stocklmayer, in preparation; Stocklmayer and Gilbert, in press).

In this research we distinguished between *short-term* outcomes, those achieved during and immediately after the use of an exhibit and *long-term* outcomes, those achieved after sufficient time had passed for the significance of the experience to be considered in a reflective manner. To evaluate long-term outcomes, we interviewed visitors by telephone several weeks after their visit.

Method

The enquiry took place at Questacon – The National Science and Technology Centre in Canberra. Interviews were conducted by a team, which included Questacon "explainers". This aspect of the study was introduced partly to facilitate ownership of the research and to remove the "them and us" idea that often results from external teams of reseachers in science centres, but more importantly to tap into the wealth of expertise which explainers possess and is often unrecognised and seldom reported in research into informal learning.

Initially we called for ten volunteers, of whom five became regular team members. The remaining five fell away through natural attrition, which was expected. The five explainers have become skilled at open-ended interviews after careful inservice and regular feedback about their techniques. The unexpected benefit for them has been an enhanced awareness of visitors' real thinking and, in their view, an ability to carry out their explainer duties more sensitively. It should be emphasised, however, that changing from an 'explaining' style to an unobtrusive interview style, which accepts all answers without the opportunity to 'correct' any perceived misconceptions is very difficult for good explainers. A compromise was reached in that we agreed that, after the interview, there would be an opportunity to discuss the exhibit further and 'help' the visitor where the explainer saw the need. It is accepted that, to some degree, this affects the follow-up interview but, since our intent is to evaluate awareness rather than to evaluate formal learning or exhibit design – and explainers are part of the Questacon experience as a whole- we must accept this modification. It is clearly unreasonable to ask explainers, whose whole ethos is to assist in understanding the concepts underlying exhibits, to allow visitors to move on with what are seen as serious misconceptions or, in some cases, only partial experience of the phenomenon.

A random selection of visitors, roughly representative by age, sex, and social-grouping-at-the-time, was informally interviewed immediately they had completed their use of one (or more) of these interactives. Interviews were audiotaped. We chose to focus mainly on adults or on older children within family groups.

A sample of those interviewed were re-interviewed by telephone some six weeks afterwards, to establish their general views on Questacon and on the exhibits that they had used, and again some three weeks later still, to identify any thoughts and actions that had been prompted by the visit. Some 150 interviews have been conducted during the two phases of the study to date.

We have considered two kinds of exhibit. One kind consisted of popular interactive exhibits which were in the category described by Rennie and McClafferty (1996, p. 56) as "self-contained and decontextualised, with reference to the real-world application peripheral to the exhibit." We have listed examples of these in Tables 1 and 2.

In Table 2, the exhibits make use of analogical representations, which are not closely linked to the target concepts which the designers identify as the desired learning outcomes.

The exhibits in Table 2 require of the visitor that they understand both phenomena – the analogical model and the target concept. This two-step process is facilitated by appropriate graphics, which explain the underlying concept.

The second kind of exhibit in this phase constituted a complete thematic exhibition called *Whodunit?* which, has a murder as the main story line and is essentially a forensic science exhibition. We were interested to see whether the more overt real-world context of a thematic exhibition made a difference to the

Table 1: Types of exhibit construction – direct analogy

Models of reduced or enlarged scale. **"Tornado"**

The Tornado explains the production and movement of a spiral of air moving circularly and transversely at high speed. It represents the phenomenon by a column of water vapour produced by a generator. This column is sucked upwards by an extractor fan at the top. The column is flanked by four vertical tubes through which lateral air jets produce the circular motion. The number of observers and their distribution around the spiral influence its pattern and its effectiveness. Visitors are advised (on the graphic panel) to cluster around in groups.

Models which provide whole-body sensations (a "ride"). **"Earthquake"**

The Earthquake model is a platform on which several visitors sit whilst it is rocked to and fro by a roller mechanism beneath it. The visitor is intended to gain a simulated kinaesthetic experience of what it would be like to be present on ground which is "quaking". The exhibit is usually staffed (for safety's sake) by an explainer, who provides an explanatory commentary tailored to the evident interests of the participating visitors

Models which provide for simple observation of a phenomenon. **"Polarised Light"**

The Polarised Light exhibit invites visitors to place a polariser in front of a beam of light and to observe various objects which include plastic forks, rulers etc. and patterns made by plastic tape. The consensus model of polarisation (wave model of light) is the model underlying this exhibit. The user is invited to discover that different orientations of the polariser cause different patterns in the field of view

Models which provide simple experimental principle apparatus to investigate a **"Roller Race"**

Roller Race relates to the rotational inertia of circular objects when rolling down an incline, depending on the distribution of the mass about the axis of rotation. Three objects of the same mass, respectively a ball, a disc, and a ring, are simultaneously released down an inclined slope. The visitor is invited to predict the order in which they will reach the bottom, to observe and then to explain the result.

way in which exhibits are discussed. *Whodunit* requires the visitor to interact in a number of different ways. The object of the interaction is to test various clues. For example, DNA, tyre treads and fingerprints of suspects can be compared, a cadaver can be examined in layers, and so on. Each exhibit requires concentrated attention to the information and its interpretation and the entire

Table 2: Examples of exhibits which are less closely modelled on the target concept

Example	Desired target concept
Light Harp The Light Harp consists of a series of small holes in which are embedded photo-sensors. About 1m above the holes are a series of light emitters whose beams may be interrupted by the user's hands and arms. As soon as this occurs, musical sounds are heard and the user may "play" the Light Harp by moving the hands across the space above the holes. The sounds are electronically generated and the user has the option to change the nature of the sounds to correspond to various musical instruments, birds cheeping, and so on.	Rectilinear propagation of light/photoelectric effect
Black Hole The Black Hole consists of a metal bowl (representing the gravitational field) into which metal balls (representing any nearby object) are dropped. The balls fall down the sides of the bowl, gaining speed as they do so, and 'vanish' down a hole at the bottom (the Black Hole itself).	The 'Black Hole', an area of space dominated by an apparently annular region of immense gravitational field.

exhibition takes time to traverse. It is less easy to interview visitors after a single exhibit interaction because of the focused nature of the whole experience and some difficulty attached to interrupting trains of thought, so we chose to interview at the exit point.

Results

In summary, we found that the choice of exhibit was indeed often influenced by existing awareness of the topic concerned (Gilbert, Stocklmayer and Garnett, 1999). For example:

I. *What do you think of the Polarised Light exhibit?*

V. *...it was involved in my business, photography and printing, that's what I used to do...But when there was a mention of polaroid for cameras...I was more interested in that aspect of it*

I. *Have you used anything like this before?*

V. *...as a yachtsman I always made sure I had a pair of polaroid sunglasses when I* *was sailing in shallow water…it cuts down the glare and you can see through the water below for any reefs* (Male, 60-69 yrs)

There is no doubt that exhibits which model real-world phenomena such as 'Tornado' and 'Earthquake' arouse empathy with those who have already experienced the phenomenon 'for real'. This sense of empathy can relate to personal experience or to distant places:

I have friends in the US and they are having a fairly serious tornado season this year… tornados just fascinate me and I had to go and see the movie…(Male, 40-49 years, a grain farmer).

and it encourages interaction.

Some visitors are drawn to the possibility of a new experience. This applies to Earthquake, for example:

I have never experienced an earthquake – I found out that I can stand up to a 5g earthquake like that and shake back and forth (Male, 60-69 years)

In these situations, information delivered either through the behaviour of the observed phenomenon or from the graphics is seen as interesting and memorable and is able to build on existing knowledge:

It is useful, a good illustration of the Richter Scale, how it is measured, the fact that it doesn't just go up, but is more of an exponential. I didn't know that before (Male, 40-49 years)

The visual impact of an exhibit was also a strong reason for choice. For example, for "Black Hole":

I liked the way the steel balls were rolling around that hard surface, they were actually rolling when I walked up to it (Female, 40-49 years)

Imagination was stirred in respect of the underlying phenomenon:

I was thinking: its elliptical. I did a second one with two marbles to see what would happen – they crashed into each other. I was surprised that in the centre they spun really fast, round and round, and stayed up for quite a while (Male, in his teens).

Even if the visitor to some of the exhibits in this group has little idea of the science, the opportunity for repeated experimentation sometimes proves compelling, as three children aged 9, 12 and 15 (female (f), male (M) and female (F) respectively) explained about Polarised Light:

Interviewer:	*What do you think of it?*
Visitors:	It's cool, it's interesting.
Interviewer:	What's interesting about it? Why is it cool?
F:	You can just stick anything on it, like my mom's glasses, she put them on there and it went all different coloured, psychedelic and stuff.
Interviewer:	So you like it because of these colours?
F:	Yeah, it's just interesting, what it does, what happens with everyday objects.
Interviewer:	So what does happen?
F:	The....I'm not sure
M:	I'm not sure...it just looks really......the light reflects off the bits of glass........and polarises.
Interviewer:	What does polarise mean?
M:	It means the light splits up into separate colours.
Interviewer:	And so what are you actually doing when you are using it?
M:	I think this is polarised glass and you look through polarised glass at other pieces of glass with things on them,.....with other reflective or semi-translucent material and you can see all the colours of the light go through them. I think that's it.
Interviewer:	What about you, would you like to add anything to that?
F:	Not really, I just look at it and go WOW; I don't really try and comprehend...
M:	Psychedelic...
Interviewer:	So you really like this exhibit and when you come to Questacon you try and make a point of using this one?
M:	Yeah, it's cool.
F:	We've done this one about five times already, it's just interesting.
f:	It's like bubbles, when you blow the bubbles they have the little rainbows on them.
Interviewer:	Did you find some of these things were more colourful than others?
M:	Yeah, some had more layers of stuff, different layers of sticky tape when they cross over.

Explanations offered by visitors about unfamiliar exhibits were, however, often qualitative, as would be expected from the nature of the exhibits used. Some explanations were descriptive, together with that most primitive of interpretations, the 'law'. All laws described were erroneous! For Roller Race:

Heavier things go quicker, it always happens (Male, in his teens)

If exhibits demonstrate an unfamiliar phenomenon, visitors can draw few parallels with real world experience or knowledge. Sometimes visitors really struggle to make connections, especially where the science language has real-world applications:

> *I had heard of polarisation...through sunglasses, mainly – and just the fact that there's polarity in so many things in nature. I'm trying to apply that understanding to what I'm seeing here... opposite poles.*(Female, 40-49 years, a water-colourist)

Not surprisingly, in cases such as these, understanding of the science behind the phenomenon was at a beginning level. Complex phenomena, such as the roller race, which demonstrates the effect of different distributions of mass around an axis of rotation using a disc, a ball and a ring, are frequently misinterpreted and, if visitors have prior conceptions or misconceptions, these may well be reinforced unconsciously by the graphic text or by selective observation. Many Roller Race observations were interpreted in terms of the ball being heavier even though the graphics explicitly stated that the "mass" of the objects was the same. Physical testing of the objects conveyed the illlusion of a heavier ball because the pressure on the hand was different. It therefore came as no surprise to these visitors that the ball won the race but their explanations were given in terms of friction, drag and so on.

School visitors were frequently observed filling in worksheets to the effect that the ball reached the end first, but not reading the graphics or, in many cases, conducting the experiment correctly. This experience was clearly of no value, and led us to wonder whether the outcomes at school were judged "successful" in the light of which boxes are ticked. Good preparation would seem to be imperative in these cases.

Many visitors do read the text, and, a small minority without prior experience, do readily accept and recall the explanation:

> *The ball rolls faster because it can use its energy for rolling fast – the energy is used more for speed than rolling. The disc came second because it needed a bit more energy for rolling and the little cylinder came last because it obviously needed most energy to roll and couldn't keep up the speed as well!... It teaches you the way that different objects use the same energy for rolling and some for speed, depending how the mass is divided up in the different objects* (Female, 30-39 years, graphic designer).

The thematic exhibition: *Whodunit?*

It came as a surprise to us that visitors to this exhibition were able to make few comments about individual exhibits. Their experience was holistic and the pursuing of 'clues' dominated their thinking:

I. *So there was nothing in particular that you found interesting, but if you had to go away and tell someone about it, is there a part that you are likely to tell them about?*
V. *No, probably just the interaction, you know, where you have to work it out for yourself...*(Male, 40-49 yrs)

Visitors had all heard of forensic science "mainly from watching programs on television" and became wholly engaged in filling in their 'crime file':

> *It requires them to be persistent, not to discount any of the evidence, not to jump to conclusions, to be very methodical...* (Male, 30-39 yrs, science teacher)

This is not to imply, however, that contributions to awareness and to understanding of the underlying science did not occur, but that they were deeply contextualised in the technological aspects of forensic science and to the 'feel' of the exhibition as a whole. Visitors almost never discussed the science concepts themselves, but explained their experience in terms of learning about what forensic scientists actually do:

> *The exhibition was a whole thing, but they've broken it down into bits and you can see what they actually do at each stage...* (Female, 20-29 yrs)

> *I can now explain each of the aspects a little bit better than I could before.* (Female, 30-39 yrs)

The technological applications are the dominant theme here, allowing visitors to access the science concepts covertly.

A drawback to exhibitions of this type can be that visitors spend much longer in front of each exhibit and queues build up at busy times. Visitors can become very frustrated if they have to wait and this detracts from the affective aspects of the exhibition. Where linear progression through a theme is required, considerations of length of engagement, time to read the graphics and so on become vitally important. Interviews of this type can, therefore, assist greatly in exhibition evaluation.

Longer-term outcomes

In the light of the short-term outcomes it is not surprising that the longer- term outcomes were generally confined to the cognitive and affective domains. What was perhaps more surprising was that, once liberated from the researcher's questions about 'what did it mean to you...' visitors were, in the longer term, inclined to give a wider range of response.

Gilbert, Stocklmayer and Garnett (1999) list a number of different ways that visitors explained long-term outcomes of the visit. In addition, it is evident that many discussions occur between family members:

We have thought about the moving dinosaurs. My daughter liked them. I can see the exhibit through my daughter's eyes. (Female, 30-39 years)

Visual memory was mentioned quite frequently:

The kids kept mentioning Lightning...they know what it looks like, have a picture in their minds, could see it (Female, 30-39 yrs)

Those who had scientific knowledge remembered the exhibit in terms of the concept portrayed:

I remember light harp... (it) showed that light travels in straight lines... (Male, 30-39, science teacher).

Reinforcement of school science was valued by parents:

We saw the chemistry show, we talked about that and actually this term at school they had a science show visit at school and my son could remember a lot of what he'd seen in relation to that so he found it really good... the children talk about Questacon a lot.(Female, 30-39 yrs)

There were many wider reflections of the science centre visit reminiscent of those described by Stevenson (1991):

(following my visit to Questacon), scientific phenomena are more interesting, less of a mystery, more understandable in terms of basic principles (Male, 30-39 yrs)

And, to conclude with the ultimate indicator of affective success in the post-modern world:

They were so absorbed (in the exhibits) that my son forgot to feed his tamogotchi. We were in the Questacon shop when he realised that his tamagotchi had died. He didn't cry... (Female, 30-39 yrs)

Discussion

We believe that this approach to the analysis of the experience of visitors to Questacon is able to illuminate some aspects of exhibit design which hinder or facilitate cognitive and affective outcomes. We believe also that it is not particularly useful to assess conventional learning of science concepts during such a visit, but that the wider picture of what visitors are really gaining is much more important.

Many of the interviews revealed ways in which the experience could be improved. They indicted problems with graphics, with exhibit design and with divergence between the designer's intentions and the public's perceptions. The research framework we have adopted here is clearly useful for exhibit evaluation generally.

More specifically, exhibit designers need to consider these aspects of interaction when designing analogical representations of this type. Clearly, expert or even partially knowledgeable visitors are able to integrate the analogy and the target and to appreciate the aesthetic and cognitive aspects of the representation in a critical way. Novices come away with an entirely different kind of learning. Exhibit designers have two choices – to understand that there will be a large group for whom the analogy is remembered but not the target concept, or to re-think how to represent the material. From the perspective of public awareness, there is no doubt that visitors remember the experience with warmth and confidence and that positive attitudes to science are enhanced by the interaction.

In summary, we assert that a visit to a science centre is likely to contribute positively to visitors' awareness of science. It remains for science centres to decide how to make the most of that contribution, whether it be through major exhibitions or through individual exhibits in a thematic gallery. For school visitors it is imperative to allow for time to explore and to accept that results of interactions will be different for each student. If enhanced cognitive outcomes are the purpose of the school visit, very careful planning, preparation of students and design of worksheets is vitally important. Such preparation facilitates engagement (through prior knowledge), successful interaction and, with good exhibit design, connections to the target.

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