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European Network of Science Centres and Museums

The Impact of Science & Discovery Centres

A review of worldwide studies

This report forms part of
The Science Centre
Enrichment Activity Grant Project

Contents

1. Introduction

This review summarises and highlights recent research into the impact of science and technology museums, zoos, aquaria and science centres, referred to collectively in this report as Science & Discovery Centres. Comparable evidence from the informal learning sector as a whole including the arts, heritage and cultural sectors has also been included, where relevant.

Collectively, studies from around the world show that:

- **There is significant evidence that interactive science exhibitions increase visitors' knowledge and understanding of science.**
- **There is significant evidence that Science & Discovery Centres provide memorable learning experiences which can have a lasting impact on attitudes and behaviour.**
- **There is evidence that Science & Discovery Centres have wide-ranging personal and social impacts and promote inter-generational learning.**
- **There is evidence that Science & Discovery Centres promote trust and understanding between the public and the scientific community.**
- **There is evidence for the economic impact of Science & Discovery Centres.**

Many of the studies referred to in this report, make reference to research that takes place in a range of informal learning environments, for example museums, aquaria, interactive galleries and other types of visitor attractions.

Ecsite-uk has not confined this review to research that has taken place exclusively within science centres since there is no robust evidence to indicate that results from one informal interactive learning environment should not be applicable to other similar informal interactive learning environments. To ignore studies outside the science centre field would be to neglect many excellent and highly relevant studies whilst overlooking that there is vast variability inherent within the science centre sector itself (and indeed within the museum sector).

We should also be clear that most countries make far less distinction than the UK between what is considered a science museum and what is a science centre, since both exist to promote science learning. In the words of Dr. Per-Edvin Persson, Director of Heureka, The Finnish Science Centre, "The difference between a science museum and a science centre is like a line drawn in water".

2. Evidence for learning in Science & Discovery Centres

There is a very substantial body of evidence for learning occurring during visits to Science & Discovery Centres, mostly from studies of families using interactive exhibits in science centres or children's museums.

Research into learning in Science & Discovery Centres has largely focused on cognitive learning outcomes since these are often the easiest to both define and to assess. Many studies have shown that there is at the very least a short-term increase (over weeks or months) in the range and depth of visitors' conceptual understanding. For example Anderson *et al* (2000) studied the impact of various interactive exhibits on school children's understanding of the principles behind electricity and magnetism. The researchers found that what was experienced in the museum was actively interpreted by the pupils (rather than just passively accepted) and incorporated into their existing mental models. Subsequent experiences of electricity and magnetism were likewise incorporated into the mental models developed during the museum experience. Similarly Beiers & McRobbie (1992) found evidence for the impact of a series of interactive exhibits upon children's understanding of the scientific principles of sound.

Evidence for the ability of exhibitions in general, and science exhibitions in particular, to stimulate learning in context and to reinforce and extend existing knowledge is significant. Numerous studies have shown evidence of visitors extending and enriching their conceptual understanding by analysing the quality of their discussions during or immediately after the visit:

> Leinhardt & Gregg (2002) found that student teachers' discussions about the civil rights movement were more coherent and contained more analysis and synthesis of information after they had visited the Birmingham Civil Rights Institute in Alabama. Prior to their visit teachers' conversations about the civil rights movement had been primarily lists of unconnected factual information.
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> Allen (2002) recorded visitors' conversations at an exhibition about frogs in the science centre The Exploratorium, San Francisco. The quality of these conversations was impressive with content-focused conversations occurring at 83% of the exhibits and representing 97% of all of the talk recorded. Much of the conversation recorded included visitors reading aloud or paraphrasing the label text. Visitors were found to engage in conceptual conversation (hypothesising, making generalisations, making reference to previous knowledge) at over one third of the exhibits.

In addition to the evidence indicating the development of knowledge and understanding, considerable evidence has been amassed of visitors to museums, zoos and science centres practising and developing skills of exploration, observation, interpreting data, sharing ideas and other skills directly related to scientific thinking (for example Allen 2002; Ash 2002; Borun, Chambers & Cleghorn 1996; Tunnicliff, Lucas & Osborne 1997; Schauble *et al* 2002; Crowley *et al* 2001a; Crowley & Jacobs 2002).

Hooper-Greenhill *et al* (2005) conducted a large-scale survey of 26,000 school children and 1,600 teachers visiting 69 museums across England. They found that both teachers and children were extremely positive about their experiences in the museums and felt that they had benefited educationally from the experience. Teachers were confident that their pupils gained new knowledge, skills and inspiration from their visit. A follow-up study of 762 secondary school pupils from nine schools visiting different museums and galleries was conducted (Watson, Dodd and Jones 2007). It was found that 60% of pupils achieved higher marks in a post-visit assessed piece of work compared to three pieces of assessed work they had completed prior to the visit.

Robin Garnett, on behalf of The USA-based Association for Science and Technology Centres (ASTC), ECSITE and other worldwide networks of science centres reviewed studies of the impact of Science & Discovery Centres from across North America, Europe and Australasia (ASTC (Garnett) 2002). Of the 180 studies reviewed, 87% were concerned with learning/personal outcomes of which 54% focused on science learning, 18% focused on attitudinal change towards science, 14% on enjoyment and 7% on Science & Discovery Centres influencing career choice. Overall, the 180 papers reviewed show science and technology centres and museums, aquaria and zoos to have a positive effect in a number of areas.

3. Evidence for affective learning

There is evidence to suggest that Science & Discovery Centres can elicit powerful emotions, which help create memorable learning experiences.

The term 'affective learning' has been used, as Roberts (1993) points out, to mean both the generation of strong emotions and the changing of visitors' attitudes. Both definitions of affective learning are relevant to Science & Discovery Centres.

Evidence based on four case studies describing the motivation of school students visiting science centres is presented by Salmi (2003) in work undertaken at Heureka, the Finnish science centre. The findings suggest that the situational motivation of students can be changed to intrinsic motivation by well organised programmes linking schools to the informal, open learning environments of science centres. In addition, a survey taken among 1,019 first and second year students at the University of Helsinki attests to the fact that informal learning sources such as science centres seem to have a stronger impact on the academic career choices of students than has hitherto been thought.

Experiences that generate powerful emotions have been shown to be more memorable and easier to recall, for example, in cases where people witness crimes (Reisberg & Heuer 2004). Exhibits and live events in Science & Discovery Centres that generate powerful emotions have similarly been shown to be highly memorable. From interviews with 75 museum professionals Spock (2000) gained over 200 anecdotes which he describes as 'pivotal museum learning experiences'. Many of these pivotal learning experiences had occurred many years previously – often dating back to childhood – providing vivid and lasting memories and, in 30-35 cases genuinely life-changing incidents.

Powerful short-term emotional impacts from a museum visit have also been demonstrated for example in student teachers' responses to the Civil Rights Institute in Birmingham Alabama (Leinhardt & Gregg 2002). In this case evoking strong emotions acted as a powerful trigger for later discussion and the sharing of thoughts and feelings. Birney (1988) found that children were most likely to cite affective outcomes (enjoyment, curiosity, happiness, fear, wonder) as a reason for visiting a zoo. Hooper-Greenhill *et al* (2005) found positive emotional responses following museum visits among both pupils and teachers.

An in-depth survey of 450 teachers (Winterbotham 2005) revealed that teachers visiting museums expected students to gain skills and develop positive attitudes towards the subject matter and believed students would acquire enthusiasm and new conceptual understanding considerably faster than they can in the classroom. The impact on them of handling artefacts and using interactive exhibits produced a profound attitudinal response and the lasting impact being one of a far more favourable predisposition to their subject area than before the visit.

The alternative definition of 'affective learning' refers to changes in visitors' attitudes. In their review of research into the impact of zoos and aquaria on visitors' conservation attitudes and behaviour Dierking *et al* (2002) found that there was very limited available evidence in part because of the practical difficulties of conducting long-term studies of actual behavioural change and in part due to the lack of a clear theoretical model for how Science & Discovery Centres impact upon attitudes and behaviour. Furthermore it has been argued that visitors to zoos, aquaria and museums are already positively predisposed to the institutions' values and messages making it difficult to elicit measurable changes in attitudes and behaviour (Falk *et al* 2007; Adelman, Falk & James 2000; Dierking *et al* 2004; Doering, Pekarik and Kindlon 1995; 1997). However as all these research studies point out an important outcome of a visit to a Science & Discovery Centre is likely to be the sustaining and reinforcing existing values. For example 7-11 months after visiting a zoo or aquarium 35% of visitors reported that the visit had reinforced existing beliefs about conservation and stewardship of the environment (Falk *et al* 2007).

A study of visitors to the National Aquarium in Baltimore (Adelman, Falk & James 2000) found that immediately after the visit there were strong emotional responses and increases in motivation to engage in environmentally beneficial activities, increased supported for conservation and increased levels of understanding about the marine environment and conservation.

Dierking *et al* (2004) studied changes in attitudes towards conservation among visitors to Disney's Animal Kingdom exhibition. By dividing the sample according to their existing attitudes towards the environment and existing conservation behaviour the researchers were able to show a degree of impact upon some visitors while not among others. The likelihood of a visitor changing their attitudes varied significantly depending upon their past history of participating in conservation activities. Those already thinking about or planning to get involved in conservation were the most likely to state increased motivation after the visit. The researchers concluded that to effectively assess

behavioural and attitudinal change arising from a Science & Discovery Centre visit, it is vital to divide the audience according to prior knowledge, attitudes and behaviour since visitors in certain categories are far less likely to show changes than those in other categories. Interestingly a subsequent study of staff working at Disney's Animal Kingdom showed positive impacts upon both their attitudes and behaviour in terms of conservation and animal care (Groff *et al* 2005).

Attempts to change visitors' attitudes have often been criticised as being simplistic, failing to take account of the complex relationship between an individual's knowledge, attitudes and behaviour. This was certainly the case in what used to be called public understanding of science where during the 1980s and 1990s an extensive programme of initiatives were run which aimed to increase the public's knowledge of science in the expectation that this would increase their support for science i.e. to know science would be to love science. Subsequent research has shown that this 'deficit model' is a poor representation of the public's response to science (Irwin & Wynne 1996; House of Lords 2000; Sturgis & Allum 2004). Increased knowledge of science tends to polarise opinions – making people more negative or more positive in their opinions. People's attitudes towards science are influenced not only by their knowledge of the subject but also by their perceptions of risk, benefit and morality as well as attitudes towards authority and other people (Evans & Durant 1995; Durant, Evans & Thomas 1989; OST & Wellcome Trust 2000).

Bob Worcester, the founder of Ipso-MORI, defines three categories of views:

1. **Opinions:** people's immediate thoughts and feelings about a topic that are relatively easy to manipulate
2. **Attitudes:** more strongly-held beliefs about the world and how it works
3. **Values:** underlying and strongly held beliefs (e.g. belief in God, animal rights, the death penalty) which are formed early in life, are very difficult to change and tend to harden as the person grows older (Worcester 2006).

Whilst a Science & Discovery Centre might be successful in changing visitors' opinions (which would be something akin to increasing their knowledge) the chances of changing visitors' attitudes and values are lower (and not necessarily desirable) given that visitors are likely to have chosen to visit the Science & Discovery Centre on the basis of their matching attitudes and values (Adelman, Falk & James 2000; Dierking *et al* 2004; Doering, Pekarik and Kindlon 1995; 1997).

In summary the evidence for affective learning is significant and indicates that Science & Discovery Centres do have powerful emotional impacts upon their visitors and can have a lasting impact upon their attitudes. Furthermore it is likely that Science & Discovery Centres play a vital role in sustaining values and patterns of behaviour.

4. Evidence for other types of learning outcome

Although far less research has been conducted into other forms of learning and societal outcomes[1], there is evidence to suggest that Science & Discovery Centres can have wide-ranging personal and social impacts.

Taking into account that evidence for personal enrichment and spiritual outcomes from Science & Discovery Centres is inevitably limited to visitors' self-assessment of their experiences, a number of studies have reported this type of outcome (Morris, Hargreaves McIntyre 2005; Pekarik, Doering & Karns 1999).

Furthermore there is considerable evidence for Science & Discovery Centres generating 'bonding social capital' (the strengthening of bonds within groups and communities) particularly within family groups. Numerous studies have shown that a key motivation for visiting zoos, aquaria, museums and art galleries is to spend quality time with family and friends and to promote intergenerational learning (MacDonald 2002; Sterry 2004; Beaumont & Sterry 2005) as well as to strengthen family bonds and consolidate the family's sense of identity (Ellenbogen 2003). This motivation was found to be stronger among visitors to zoos compared to those visiting museums and art galleries (Pekarik, Doering & Karns 1999).

There is some evidence for museums and Science & Discovery Centres promoting 'bridging social capital' (the development of links between different communities), as shown in recent reviews of the impact of the UK's national and regional museums and galleries. These organisations were found to have contributed 101 touring exhibitions and loans of objects or artworks to other UK museums and galleries in 2000-2001 (Travers & Glaister 2004). It was also found that the national museums and galleries had established 244 links with UK universities, 81 with overseas universities, and 52 with UK-based Further Education Colleges and 30 strategic partnerships with regional museums.

Scott (2003) conducted an in-depth qualitative investigation of the impacts visitors and museum professionals believe museums should have. Both visitors and museum professionals believe that museums contribute to the development of communities – building identity, social cohesion and a shared heritage. Both groups also felt that museums increase contact among communities and help to build social networks. On a more personal level both groups felt that museums encourage creativity and provide inspiration for their visitors.

Science & Discovery Centres have been shown to be developing 'bridging social capital' between scientists and the public through dialogue-events about contemporary science issues (Davies *et al* 2007; Lehr *et al* 2007). One of the aims of such events is to build trust and understanding between the public and the scientific community and there is evidence that these aims are being achieved.

[1] In part because these have only recently begun to appear in models of informal learning and in part because such outcomes are much more difficult to define and assess.

Matarasso (1997) surveyed 243 adults and 270 children who had participated in arts events across the UK. Overall responses were very positive with 91% reporting that they had made new friends; 54% that they had learnt about other cultures; 63% that they were keen to help in future local projects and 73% that they were happier since being involved in the project.

In terms of providing other benefits to society Hooper-Greenhill *et al* (2005) found evidence that museums are successfully engaging children from some of the most deprived areas of the country. For example a higher than expected proportion of schools from deprived neighbourhoods visited the museums with 32% of the visits made by schools from the most deprived areas of the country. It was also found that 38% of schools visiting the museums came from the top quartile for numbers of pupils entitled to free school meals (a key indicator of deprivation); and that there was a higher than expected number of Special Schools making use of the museums (12% of the visits were from Special Schools which comprise just 5% of schools in England).

Collectively these studies would appear to indicate that Science & Discovery Centres are forging links between communities and delivering positive societal impacts.

5. Evidence for long-term learning

There is significant evidence to suggest that Science & Discovery Centres provide lasting benefits.

Falk & Dierking (1997) interviewed adults and children aged 9-10 and 13-14 years old about past trips to Science & Discovery Centres. They found that even after a gap of several years both adults and children could recall many aspects of the experience including content or subject-related information (77% of memories); details of the physical setting (56% of memories); emotional responses to the experience (55%) and details of the social aspects of the visit (47%). Of the adults and children interviewed, 80% claimed to have thought about the Science & Discovery Centre experience afterwards. Similarly Anderson *et al* (2002) assessed pupils' memories four to six years after visits to various types of museums and science centres. They found a diverse range of memories especially about large-scale objects as well as kinaesthetic and multi-sensory experiences. Anderson (2003) found that visitors to the 1986 and 1988 World Expos were still able to recall memories of their experience some 12 or more years later.

Stevenson (1991) looked at the impact of a major interactive science exhibition immediately after the visit, a few weeks later and then after six months. It was found that even after six months visitors were able to spontaneously recall details of their experience. Around 26% of memories – most of them fairly detailed – were spontaneous and most people could spontaneously recall five different exhibits. Around half of the memories elicited either spontaneously or with prompts were detailed and clear. 60% of the exhibit memories were descriptions of what the visitor did at the exhibit and 14% refer to their feelings about the experience. 26% of the memories reflected visitors' subsequent thinking about the exhibit's content suggesting that there

was at least some cognitive processing of the experience rather than just the recalling of isolated episodic memories. Interestingly visitors quite often linked their experience to what they had seen on television. Similarly Beiers & McRobbie (1992) found evidence of children integrating the Science & Discovery Centre experience into pre- and post-visit mental models over the course of a few weeks.

The evidence for the lasting impact provided by Science & Discovery Centres is corroborated by the Falk *et al* (2007), who showed that 7-11 months after visiting a zoo or aquarium, 65% of visitors were able to talk about what they had learnt from their visit.

Spock (2000) and Anderson (2003) found evidence for extremely powerful memories from Science & Discovery Centre visits dating back years and sometimes even decades. These memories included content of the displays, social aspects of the visit, layout of the exhibitions, emotional responses, events subsequent to the visit that led to recall of the experience and memories about the visitors' socio-cultural identity at the time of the visit. Indeed what the visitor remembers seems to be profoundly influenced by who they were at the time e.g. child, pupil, parent, volunteer staff member (Anderson 2003).

There is evidence too that learning outcomes may change over time and that, for instance, an initial increase in knowledge and skills may be followed by a subsequent change in attitude. Assessing learning outcomes immediately after a visit and then four to eight months later (Falk *et al* 2004) found that initially learning outcomes were primarily increases in knowledge and skills, however after four to eight months impact was found to be mainly changes to perspectives and awareness with a drop in the number of people reporting knowledge and skills increases and a slight increase the number mentioning social outcomes.

Evidence for long-term changes in attitudinal and accompanying behaviour is less positive. While Spock (2000) demonstrated that Science & Discovery Centres can have profound, life-changing impacts upon some visitors his study was too small and the sample too specialised to be able to draw convincing conclusions about the impact upon the general public. Large-scale quantitative studies of attitude and conservation behaviour following a visit to the National Aquarium in Baltimore found that after just six to eight weeks most of the immediate affects had faded with most visitors returning to pre-visit conditions (Adelman, Falk & James 2000). Similarly changes in attitude towards the environment and motivation to engage in conservation activities following a visit to Disney's Animal Kingdom were found to have been lost within two to three months (Dierking *et al* 2004). In both cases the researchers argued that without subsequent reinforcing experiences it is perhaps not surprising that the impact of a Science & Discovery Centre visit fades away.

Jarvis & Pell (2005) conducted an extensive study of the long-term impact on 300 children aged 10-11 years immediately and three months and five months after a visit to the National Space Centre in Leicester. The pattern of impacts was complex with children who were already interested in science showing no change with their enthusiasm remaining high over the five months of the study. Another group of pupils showed significant increases in their levels of interest that were sustained over five

months. However for the majority of the children (62% of the boys and 71% of the girls) there was no overall long-term impact. Despite an initially positive impact upon attitudes and enthusiasm for science created by the visit to the science centre, in-depth interviews with the children revealed that the positive experience of the visit was subsequently undermined by negative school experiences. In other cases it was found that the impact of the visit was dramatically affected by the quality of the teacher's preparatory and post-visit work with the children and whether or not the children received encouragement at home. In summary although for most children no long-term impact could be found for the visit this was due to the confounding influence of factors outside of the control of the Science & Discovery Centre.

These studies appear to indicate that Science & Discovery Centres can have lasting impacts and that much of what visitors have learned is retained long after the time of their visit. Where evidence of lasting impact was absent, this was deemed to be due to negative factors outside the Science & Discovery Centres' control.

6. Evidence of economic impact

There is some evidence from comparable sectors that Science & Discovery Centres can have significant economic impacts.

The National Museum Directors' Conference commissioned a study of the economic impact of national museums across the UK (Travers & Glaister 2004). Using Treasury-agreed formulae and data collected from all 29 of the UK's national museums the authors estimated:

- Turnover in 2003-04 of £715 million
- £565 million spending generated by the visitors
- 6.1 million visits by children
- 3 million people in on-site formal learning activities
- 5.6 million people in off-site formal learning activities
- 10,301 full-time equivalent employees plus between 13,000-21,000 jobs generated in dependent and related industries
- £320 million per year of overseas exports.

The study also provides a series of case studies which indicated that national museums (including science museums) support a variety of creative industries. The following members of Ecsite-uk were part of this study:

- National Maritime Museum
- National Museums and Galleries of Wales
- National Museums Liverpool
- National Museums of Scotland
- Natural History Museum
- Science Museum

In the USA, ASTC commissioned an assessment of the economic impact of science centres across the world upon their local communities (Groves 2005). Questionnaires were sent to 700 science museums, science centres and similar organisations across five regions – North America, Latin America & the Caribbean, Europe & the Middle East, Asia-Pacific, and Southern Africa. In total 199 institutions returned questionnaires - a response rate of 28% (including 26 Ecsite-uk member organisations;13% of total respondents). Three quarters of the responding organisations were science centres. Data was collected for the financial year 2001-02. The aggregated data from the 199 institutions showed:

- Total operating expenditure of US$1.1 billion (54% on salaries and other staff costs)
- Total capital expenditure of US$308 million
- 61.8 million on-site visitors
- 15 million off-site visitors
- 10,756 people in full time employment
- 6,123 people in part time employment
- 26,546 volunteer staff

Groves points out that it is not possible to extrapolate from this sample to get a figure for the overall impact of all Science & Discovery Centres Centres since the sample only represents 25% of members of the networks approached. Firstly it is unclear to what extent the sample obtained is a representative cross-section of the different types and sizes of Science & Discovery Centres (some may well be over- or under-represented) and secondly not all centres will be part of the local networks.

Given these caveats, this survey would still appear to indicate that worldwide Science & Discovery Centres are having significant economic impacts.

7. Conclusion

As part of a worldwide community of Science & Discovery Centres and Museums we acknowledge that our understanding of the impact of Science & Discovery Centres is far from complete and there is undoubtedly a need for further research in particular to fully investigate the long-term impacts of Science & Discovery Centres.

However, there is now a growing body of evidence from around the world, some of which is reviewed here, which points towards the many varied and substantial impacts of Science & Discovery Centres in their broadest context.

Appendix

How have Science & Discovery Centre impacts been measured and described?

As part of their Inspiring Learning for All initiative the Museums Libraries and Archives Council (MLA) proposed a taxonomy of five types of learning outcome for all museums, libraries and archives (www.inspiringlearningforall.gov.uk). This has now become the standard definition of educational benefit for museums in England and is used by a growing number of Science & Discovery Centres.

The MLA's generic learning outcomes

Outcome	Examples
Knowledge & understanding	Learning facts or information Making sense of something Deepening understanding Learning how museums, archives and libraries operate Making links and relationships between things Using prior knowledge in new ways
Skills	Intellectual skills – reading, thinking critically and analytically, making judgement Key skills – numeracy, literacy, use of ICT, learning how to learn Information management skills – locating and using information, evaluating information, using information management systems Social skills – meeting people, sharing, team working, showing an interest in the concerns of others Emotional skills – recognising the feelings of others, managing feelings Communication skills – writing, speaking, listening Physical skills – running, dancing, manipulation, making…
Attitudes	Opinions about ourselves e.g. self-esteem Opinions or attitudes towards other people Attitudes towards an organisation e.g. museums, archives and libraries Positive attitudes in relation to an experience Negative attitudes in relation to an experience Reasons for actions or personal viewpoints Empathy, capacity for tolerance (or lack of these)
Enjoyment, inspiration, creativity	Having fun Being surprised Innovative thoughts, actions or things Creativity Exploration, experimentation and making Being inspired
Action, behaviour, progression	What people intend to do (intention to act) What people have done A change in the way that people manage their lives including work, study, family and community contexts Actions (observed or reported) Change in behaviour Progression – towards further learning, registering as a library user, developing new skills – is the result of a purposive action which leads to change

The MLA's generic learning outcomes: a critique and other models

This taxonomy of learning outcomes was based upon an extensive review of current research into museum-based learning (Moussouri 2002) and is very similar to those used in previous research studies of visitors' learning (e.g. Anderson *et al* 2002 and Falk *et al* 2004), which in turn are based upon Bloom's taxonomy of learning outcomes (Bloom 1956).

The evidence that had been presented for the impact of museums and art galleries, prior to the introduction of the ILFA framework, has been severely criticised. Wavell *et al* (2002) reviewed five years of evidence from the UK museum sector for social, economic and educational impact. It was found that:

- There is often a confusion of aims between finding evidence of impact and advocating for the value of an initiative
- Much data is anecdotal and often relies upon reports of project staff rather than evidence obtained from visitors
- Most reports cover specific projects, rather than the impact of core services, and focus upon immediate rather than long-term impacts
- Many reports fail to provide data on the audience profile or to give details of the methodologies used
- There is no systematic methodology for defining or assessing the sector's impact
- There is a lack of hard evidence of causation
- There is a lack of research skills among museum professionals and a lack of incentives for organisations to provide robust data.

This review accords with other reviews of impact data available from the museum and art gallery sectors (Selwood 2002; Kelly & Kelly 2000) and may present valuable lessons for the Science & Discovery Centre sector.

Pekarik, Doering and Karns identified four categories of satisfying experience from interviews with visitors at various Smithsonian museums, art galleries and zoos:

i) object-centred
ii) cognitive
iii) introspective
iv) social

Their data showed that different types of institution tend to generate different patterns of experience with zoos generating more social experiences, museums cognitive experiences and art galleries object-centred and introspective experiences.

Kelly (2003) reviewed various studies of visitor and staff perceptions of museum-based learning. She found that both visitors and staff distinguished between learning for education (perceived to be forced and viewed negatively) and informal museum-based learning driven by visitors' own interests and where they have personal choice and control over the experience. Visitors' expectations of museum learning outcomes included gaining information and new insights; developing knowledge and skills; changes to attitudes; changes in self-perception.

Social outcomes

Morris, Hargreaves, McIntyre (2005) identified a number of potential outcomes from a museum visit supported by over 8000 interviews and 4000 observations of museum visitors, including 'social outcomes' – social interaction, entertainment, inclusion, access, comfort, 'intellectual outcomes' – interests, self-improvement, 'emotional outcomes' – aesthetic pleasure, awe and wonder, personal relevance, experience of the past, nostalgia, sense of cultural identity and 'spiritual outcomes' – escapism, contemplation, stimulation of creativity.

Increasingly, researchers, Science & Discovery Centres and funders are also interested in the benefits gained by wider communities or by society as a whole. Matarasso (1997) identified 50 individual and societal impacts of participating in arts programmes. These 50 outcomes were grouped into six categories (the last three of these referring to impacts upon the wider community rather than upon individual visitors):

i) personal development
ii) stimulating imagination and creativity
iii) promoting health and well-being
iv) social cohesion
v) community empowerment
vi) promoting local culture and sense of identify

Kelly & Kelly (2000) proposed five categories of outcomes for both individual visitors and the wider community arising from the arts and creative industries:

i) social benefits (increased employment, safer communities)
ii) social capital (the sharing of ideas, information and values; the development of empathy and understanding of other people's ideas and culture)
iii) building and developing communities
iv) social change (increasing public awareness of issues, changing attitudes)
v) human capital (improving communication skills, problem solving abilities, creativity, social awareness).

Overall there is a clear consensus regarding the outcomes museums, art galleries, zoos, science centres and similar organisations should be achieving both for individual visitors and for society as a whole.

Long-term learning outcomes

As one might expect, less work has been carried out into the long-term learning outcomes (in Science & Discovery Centres and in museums) probably because of the inherent difficulties of conducting these studies including:

- How to maintain contact with a representative sample of visitors over a period of months
- How to avoid unduly influencing visitors' responses by maintaining such prolonged contact
- Staffing and other costs associated with research lasting months or even years
- Technical expertise required to conduct studies of long-term impact

- Difficulty of proving causation e.g. has visiting the museum led to students studying science at A' level or are students interested in studying science at A' level more likely to visit museums?

Most long-term impact studies have been carried out by academic researchers rather than staff at Science & Discovery Centres (for a good example of a recent study of long-term impact see Jarvis & Pell 2005). There is still considerable debate as to what long-term impacts can be expected and how to measure such impacts. What is clear is that the assessment of long-term impacts is a formidable undertaking partly because it is difficult to know how to isolate the impact of the Science & Discovery Centre visit from the myriad of other experiences before and after the visit. The constructivist model of learning proposes that what visitors learn will be hugely influenced by their past experience, prior knowledge, interests and the culture from which they come (Falk & Dierking 1992; 2000; Hein 1996; Falk, Moussouri & Coulson 1998; MacDonald 2003) as well as their age, gender, frequency of visiting and the type of social group they are in (Falk *et al* 2004). Similarly the experience gained at the Science & Dscovery Centre will be re-interpreted in the light of subsequent experiences (Falk & Dierking 1992; 2000; Beier & McRobbie 1992; Stevenson 1991). As summarised by the National Association for Research in Science Teaching:

> *'Learning that occurs today depends on yesterday's learning and is the foundation for tomorrow's learning.'*

This means that predicting learning outcomes is extremely difficult and the learning outcomes for each visitor will be highly personal and unique. Unlike learning in a school setting it is not possible to precisely prescribe the learning outcomes of a Science & Discovery Centre visit and therefore different methods of assessment are required. As Falk & Dierking (2000) describe it:

> ***'Over the years providing compelling evidence for learning from museums has proved challenging. This is not because the evidence did not exist, but rather because museum learning researchers, museum professionals, and the public alike historically asked the wrong questions and searched for evidence of learning using flawed methodologies.'***

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Acknowledgements

With grateful thanks to Dr Ben Gammon for undertaking all the original research work in the early preparation of this review, and to Emmie Kell for reviewing and editing this final position paper.

Ecsite-uk would like to thank the following people for their comments and advice: Dr. Per-Edvin Persson, Director of Heureka (The Finnish Science Centre), Dr Nick Winterbotham, Director of Thinktank and Chair of Ecsite-uk, Sean Gaffaney of MOSI and Dr Sue Cavell, Head of research and evaluation at Techniquest.

Dr Penny Fidler, Director of Ecsite-uk