VITENSENTRENE
skaper realfagsglede

Towards a framework for exhibit design and evaluation

Written as an item for discussion at the math-exhibit-development seminar

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Introduction

This paper is written with the intention of initiating discussing the development of a framework for designing and evaluating interactive science exhibits. It will be sent to all participants in the math seminar to be held at the Science Project, London, March 2017. The participants will be developers from all ten science centres in Norway and staff at the Science Project.

We consider design and evaluation as two sides of the same coin. An exhibit is designed to generate certain learning related behaviours, and evaluation is based on identifying occurring visitor behaviours. The three texts that this paper is composed of, represents three different perspectives in a discussion towards a common framework. This paper is meant as a start of the discussion, and therefore, there is no summary or concluding remarks. Further development towards a framework is depending on the result of the discussion at the seminar.

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Expand – Exploring and Expanding Science Center Research (UtVite – utforsk vitensentrene), by Aiyana

About the Expand Project

Expand – *Exploring and Expanding Science Center Research* is a collaboration between Statoil, INSPIRIA Science Center, The Division of Teaching and Teacher Education (SLL) at NMBU – The Norwegian University of Life Sciences and The Norwegian Center for Science Education at Oslo University (UiO). The project consists of three main people: project leader Associate Professor Merethe Frøyland at the Norwegian Center for Science Education, UiO; Professor Dagny Stuedahl, employed as a researcher at NMBU; and Ingrid Eikeland, a doctoral student at NMBU. The project started in 2011 and is set to end in 2017.

Initiation of the project arose as a result of two evaluations of the Norwegian Science Center program Quin, 2006; Persson *et al*., 2009) and a biography of Norwegian science studies from 2003 to 2010 (Nordahl, 2010). These studies articulated several needs related to gaining a deeper quantitative and qualitative knowledge of the science centers' overall impact on and stimulation of science learning and recruitment to the field of science. The program has three focus areas, based on needs that were highlighted in the publications: 1) science as a learning arena, 2) involvement and recruitment to science, and 3) development of reflection practice within the Science Center community.

The Expand research program is an important research project for all of the now ten Norwegian science centers. It aims to explore some of the challenges facing Norwegian science centers, as well as science centers in general. By initiating and conducting higher educational university courses for science center staff, Merethe Frøyland and Dagny Stuedahl were able to challenge the staff to consider how to observe their audience in interaction with science center installations; they were also able to initiate a reflection process of science centers' practice in general.

As part of the course, eight science centers were actively involved in the research, collecting and assessing quantitative and qualitative data from the exhibitions as part of the courses. This data will assist in evaluating both the quality and significance of the science centers as valuable learning institutions.

Science Center Installations

All science centers have exhibitions, consisting of a collection of installations that present various scientific phenomena. In line with science center founder Frank Oppenheimen's aim when opening the Exploratorium in 1969, visitors are expected to gain knowledge of and an interest in science through active engagement and interaction with the installations. Several studies show that interactive installations stimulate and engage more than static installations do (Hornecker and Stifter, 2006). However, studies also show that interactive installations may cause misunderstandings and confusion.

There may be several challenges associated with the interaction between installation and audience. If the goal of the installation is to stimulate the visitors' learning process, the design of the installation is important. The action that the visitor is supposed to take in order to achieve an anticipated reaction or outcome has to be clear, so that there are no misunderstandings. The information has to be understandable as well as interesting, and there has to be a link between the action and the desired learning that the installation is designed to convey. This is a complex task.

Another challenge in communicating science in general is that one often has to resort to simplifications or models, such as those found illustrated in numerous textbooks in our schools. When presenting a model or an installation, an assessment must be made. One has

to choose what to focus on, and how to portray the scientific phenomenon, in order to make sure the desired goal of learning is achieved.

In the science centers, an additional complication is the dissemination of science to an audience of various ages, backgrounds and levels of knowledge. An ideal science center installation should offer potential learning for all visitors, or at least should arouse some sort of wonder and/or fascination, that may generate interest or lead to potential learning later. One could argue that an exhibition with an overarching theme has a desired story to convey. Each installation will then have its own story to tell as part of a larger picture. The interaction between the visitor and the installation can then be viewed as a dialogue. If the installation is produced with the goal of providing learning, it needs to be constructed in such a way that the story the installation is supposed to tell is received as anticipated by the audience. All these challenges highlight the need to develop didactics and support structures to analyze, design and redesign installations so that they may lead to involvement and learning.

Making Thinking Visible

As part of the Expand research program's course for science center staff, installations were assessed on the basis of the audience's interaction with the installation. *How is the installation used by Science Centre visitors? What are they left with after using the installation? Does the installation manage to tell 'its story' in the absence of an educator or facilitator assisting in the 'story telling'? Do visitors learn anything, and if so, do they learn what the installation was designed to convey?* These are some of the initial questions asked during the science center staff course. In light of these, a new question appeared. *How do we observe learning when we know that learning is a complicated process, often requiring several steps and adaptations?*

There are a number of different methods used in attempting to document learning. Our school system is built upon testing. However, from both theoretical knowledge and experience, we know that the learning process is a complex phenomenon. Learning does not necessarily occur just because one has been exposed to information. Learning is dynamic. It builds upon previous knowledge and experience, is an ongoing process and varies from person to person.

One may argue that in order to apply and work within a subject – to explain, analyze and reflect within it – one has to have a thorough understanding of the topic at hand. Thus, the theme should already be learned. However, it might also be argued that actions performed in the process of reaching a deeper understanding of a subject – explaining, analyzing, reflecting – may each be regarded as good processes to acquire learning (Wiske, 1997).

Ritchhart *et al*. (2011) describe how a list of eight identified thought processes can be used to observe students during learning activity in classrooms. Although these eight identified thought processes have not previously been used to analyze learning by interaction with installations, Merethe Frøyland implemented this theory as a tool to analyze visitors' interaction with science center installations during the Expand course.

The thought processes

1. Observing closely and describing what's there
2. Building explanations and interpretations
3. Reasoning with evidence
4. Making connections/links
5. Considering different viewpoints and perspectives
6. Capturing the heart and forming conclusions
7. Wondering and asking questions
8. Uncovering complexity and going below the surface of things

We cannot claim that by observing these thought processes we have documented learning. However, several of these eight points have been identified as essential to the process of learning (Ritchhart *et al*., 2011), and an installation that stimulates such thought activities will thus have a higher learning potential.

During the two courses, visitor's interactions with several installations were observed. Each science center chose at least one installation where interaction was viewed as not optimal. The observations were documented, analyzed and used to pinpoint alterations that might enable the installation to stimulate 'visual thinking'. How might a redesign draw attention to a desired location on the installation, or to desired information? Would alterations stimulate visitors to interact and share dialogue while exploring the installation (Vygotsky, 1978)? Could the task or action that visitors are supposed to make be simplified and cause less confusion?

The results from the two courses showed how, in some cases, minor alterations helped visitors to gain a much better understanding of a phenomenon. Implementing information from the text into the 'dialogue' of the installation was seen as a positive alteration that simplified interaction. Lighting and positioning of the installation within the room had a huge impact in some cases. Designing the installation so that it invited social interaction and enhanced dialogue led visitors to stay longer at the installation (holding power) and hence enhanced the visitors' ability to uncover its complexity, capture the heart and form conclusions.

The Expand research program has already shown itself to be highly valuable. It has assisted the science centers in developing didactics for enhancing and documenting potential learning within their exhibitions. However, it has also given the science center community valuable support structures and tools to be used in the designing of new installations.

Active Prolonged Engagement (APE), by Nils Kristian

About the APE Project

The APE project is one of many projects that grew out of a research group at the Exploratorium in San Francisco, the first science centre in the world, established by Frank Oppenheimer in the 1960s (Cole, 2009). When the centre was established, it had a clear objective: to stimulate the audience's curiosity and wonder with regard to science and technology by allowing the audience to explore and observe phenomena in the exhibition. Observation and perception were therefore important parts of the centre's philosophy, often made with an artist's glance at the phenomena. Therefore, from the start, an artist was associated with the centre, an ‘artist in residence’.

Museums have traditionally represented research-based knowledge and are therefore often associated with universities. The institutions preserve and carry out research on both nature and culture in addition to conveying knowledge to the public. They can therefore be regarded as an authority in their fields. Science centres have no responsibility for conservation or research in science and technology, but aim to stimulate the wonder and curiosity of the individual, by facilitating exploratory activities that, in time, may create a persistent fascination and interest in the subject. This can, in turn, be an impetus and cause an internal motivation to understand more, which can lead to learning. Science centres will therefore not be authorities in science and technology disciplines to the same extent as museums are; they should, however, be authorities on the dissemination of science in a popular way, often based on their own research in the field. Since interactive exhibits have been a key element in most science centres, they have been and still are an important arena for research.

Initially, the audience was ‘taken by the hand’ and guided through various experiments, often using a detailed description of what to do and what they should notice, before being given the ‘right’ explanation. Eventually, this strategy was called ‘planned discovery’, a kind of facilitated exploration. Although many things are about to change, this kind of exhibits are found in most science centres and is in many cases an appropriate strategy for experience and learning.

Over the years, the staff of Exploratorium in San Francisco realized that instead of facilitating for planned discovery, it should present an issue to visitors and give them the tools (the exhibition) they needed to explore the issue or phenomenon through play, experimentation, observation and reflection. The key to the success of this strategy is creating a commitment that is reinforced and deepened through the work of the interactive exhibition. In this way, the science centre gives up its authority as a base of knowledge and leaves it to the audience to ask questions and seek answers. Exhibitions of this kind will therefore have few instructions and only help visitors to get started. In this way, the focus moves from the science centre as an active disseminator of knowledge to the visitors as active and engaged explorers. When the engagement increases, the visitors stay longer at the exhibit. This new way of thinking, interactivity was therefore called ‘Active prolonged engagement’ or APE.

If one’s goal is for visitors to leave the science centre with an increased and corrected understanding of science and technology, then this latter strategy is particularly risky, since one knows very little about the background of the visitors arriving at the centre. Consequently, the visitors have significant opportunity to interpret the questions and observations in their own way and according to their own world of imagination. One can hope

that the visitors leave the science centre with a greater commitment and a feeling that what they have discovered is *their* discovery, which may in retrospect, have greater value for them than a complete and accurate scientific understanding. However, proper scientific understanding must not be regarded as of secondary importance; rather, one has the belief that genuine engagement will sooner or later, lead to proper understanding.

However, it is not easy to build an interactive exhibition that will stimulate exploration by visitors. It is often only small details that distinguish a good exhibition from one that is not working as intended (Humphrey, 2005). When starting the APE project at the Exploratorium, there were three key questions that were asked:

1. Would an attractive first impression compromise prolonged engagement? A prerequisite for visitors to become involved in an exhibit is that the first impressions give them the urge to approach the exhibit. Prolonged engagement will require rich opportunities to explore the exhibit, but such diversity may discourage visitors when they encounter the exhibit. Thus, it is possible that visitors will be scared away before they have an opportunity to engage. The complexity of the exhibit must therefore gradually be revealed to visitors while they are working with it. We can talk about a *hidden complexity.*

2. How can we leave the initiative to visitors without leaving them feeling helpless and frustrated? Some visitors will feel lost without a clear description of what to do and an explanation of what is happening. It is difficult to engage with an exhibit where the initiative is left to the visitor. In such a situation, it is important that the mission is so clear and expressed so simply that the viewer perceived immediately. Moreover, it must be easy to see where one starts exploring the exhibits. The visitors must then uncover new opportunities for themselves. In other words, the threshold to get started must be low and so tempting that it captures the visitor's interest in the exhibit. On the other hand, the threshold for leaving the exhibit should be high.

3. How is it possible to take into the consideration of the diversity of the visitors, each on their own level, without leaving the majority frustrated? They are diverse in terms of their age, each with his or her own experience and knowledge background. Meeting everyone's needs would seem like an almost impossible task. One must therefore often make compromises with regard to visitors and age.

The Exploratorium organisers realised that these questions raised enormous challenges in the selection and design of exhibits. The whole purpose was to change the visitors from passive recipients to active and engaged participants, asking questions like, '*What happens if we do this?'* If one succeeds in this, the science centre ceases to be a place where authority conveys truths and becomes a place where the visitors build knowledge through experience.

Answers to these questions appeared in an education trend that emerged in the late 1990s and has continued into this millennium. Thomas Humphrey at the Exploratorium writes, 'People seemed to be responding to a kind of guided freedom that invested in them the authority to participate actively in their own learning. (Humphrey, 2005, p. 2)

This is what we today call *Inquiry-based learning*. At the Exploratorium, they set up a list of key guidelines to develop interactive exhibits of the kind they wanted:

- Gently give instructions to get visitors started, but make sure that exploration is open-ended.

- Provide support to public exploration by reducing instructions and explanations to a minimum. Encourage the visitors to observe, speculate, play and construct.
- Ensure that the visitors' role shifts from being recipients to becoming active participants (along with the centre's employees and other visitors) who ask questions, initiate activities and suggest explanations for what they observe.

Other science centres in the United States had already begun to experiment with variations of such exhibitions.[1] These centres set aside special areas in the exhibition for such exhibits. However, the Exploratorium wanted to distribute them *among* the other, more traditional exhibits.

The goal was clear. They wanted

> *... to generate specific kinds of visitor-driven behaviour, including questioning that generates exploratory activity, critical and uncritical observing, investigating along branching paths, collaborating with other visitors, and searching for and reflecting upon causal explanations for exhibit phenomena. (Humphfrey, 2005, page 3 (top centre slot))*

This is a praiseworthy proposition but since it is difficult to know what basic knowledge the visitors bring with them and how they think, it was quickly realised that there was no simple way of knowing how successful an exhibit was. It was necessary to find out how long the visitors stayed by the exhibit, why they chose to leave it, questions and conversations that took place in conjunction with the exhibition, and other indicators of the quality of public involvement. In other words, the Exploratorium organisers sought to identify the properties at the exhibits that encouraged the visitors to engage and stay at an exhibit for a longer period, so-called 'APE behaviour'. To figure this out, they conducted observations, video recordings, interviews and measurements of the average time of use by visitors. The latter became an important indicator of the visitors' engagement (Gutwill, 2010).

What Are the Key Factors of a Good Interactive Exhibit?

There are a number of different definitions of what interactive exhibits are. McLean (1993) defines an interactive exhibition as follows:

> *... those [exhibitions] in which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input.* (p. 93)

I have chosen the following definition for the interactivity of an exhibit:

> *Interactivity is the interaction between an exhibit and one (or more) person(s) so that different stimuli from the person(s) provide different responses from the exhibit. There should be a connection between stimulus and response that underpins understanding (learning) of a phenomenon or a technology.*

An interactive exhibit has some characteristics that I think are important. At the moment, most of these are unsubstantiated claims and can form a set of hypotheses that can be tested against observations and interviews among visitors.

[1] Science Museum of Minnesota (SMM) and Museum of Science Boston (MOSB)

1. Surprising

This means that an exhibit is surprising, which is important to capture the public's interest, create curiosity and draw crowds to the exhibit. Some refer to this as the exhibit's 'Attracting power'. This may be a surprising phenomenon, a response or a cognitive paradox.[2]

2. Clearly/goal-oriented

Once the exhibit has captured visitors' interest, it is important that they as quickly as possible become aware of what the purpose of the exhibit is and what problem it raises. This issue should not be too complex or intricate. It is best if the exhibit uses techniques with which visitors will be familiar (Shaby, 2016). It may be operating the exhibit by cycling, pulling a rope, throwing a ball, turning a steering wheel and so on.

3. Can be manipulated

This is perhaps the most important attribute of an interactive exhibit. However, it is not enough that it can be manipulated; it must also be possible to manipulate the exhibit in different ways. This makes it possible to explore the exhibit, and thus is closely linked to the 'richness' of the exhibit. What I have chosen to call a 'push-button' exhibit can be manipulated, but if the user presses the button, the same thing will happen every time. Such an exhibit allows for observation, but the opportunity for active exploration of the phenomenon is limited. It would be like trying to get to know a person just by asking one simple question.
Another important point with interactive exhibits is that the visitors should have the feeling of controlling the exhibit and not that the exhibit controlling them. Installations that override visitors create frustration and confusion. Therefore, visitors should be given as much control as possible without overwhelming them with opportunities (Rossing, 2016).

4. Repeatable

If we are going to explore a phenomenon, it is usually crucial that the same stimuli give the same response. If this is not the case, we say that the exhibit is unstable and needs servicing. Alternatively, it may be that the phenomenon being studied is so marginal that other phenomena hide the phenomenon to be investigated. This does not apply, of course, to exhibition models exploring random processes. Were we to be examining a stochastic process, we would expect accidental occurrences, albeit occurrences that would be predictable. At the Science Centre in Trondheim a few years ago, we had a wheel of fortune intended to show visitors how incredibly lucky they were to be born into a rich country like Norway. By turning the wheel, it was clear that the likelihood of being born into poverty and chaos was substantially greater than the likelihood of being born into affluence.

5. Immediate

The whole atmosphere at a science centre should be prepared for a high tempo and little patience. This seems to be particularly pronounced for children and youth who come as a group without a clear objective for the visit. An exhibit intended to provide a stimulus has to give a clear response in a few seconds. There are, however, major differences with regard to patience, both with respect to age and among visitors generally. It requires a fair amount of discipline not to lose focus when so many things are occurring simultaneously in the science centre exhibition. Plenty of space between exhibits or small separate rooms will make it easier to stay focused.

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[2] J.P. Gutwill argues, however, that 'cognitive paradoxes' are rarely particularly suited to stimulating exploratory activities. He offers two reasons: 1. The possibilities of manipulating an exhibit to create an effective paradox are limited, and 2. a consequence is that visitors more often than not have trouble obtaining answers to their questions through manipulation of the exhibit. Although such exhibits are suitable for learning, they can still help create wonder and curiosity (Gutwill, 2008)

6. Insight (open)

It is our experience that mechanical models that offer good insight into what happens are the exhibits that the public like best. ‘Fastest runway’ is one such exhibit. Visitors release two balls (or cars) from the same point, and then follow the two balls along two different paths down to the same endpoint. It turns out that the ball following a route longer than the straight line, finishes first. Although the result is unexpected, the visitors are given a full insight into what is happening and can control all the parameters. Our experience was that, after a while, most of the visitors realised that on the curved and longest path, the projectile had greater acceleration at the beginning of the run and therefore a higher average speed, which compensated for the longer road. Less easy to establish is the fact that the fastest path is a cycloid.

7. Socialisation

Exhibits that require cooperation bring people together and stimulate discussion and participation, which deepen the engagement of the visitors. Shaby et al. (2016) describe exhibits that are able to ‘support large groups’, referring to exhibits where the visitors waiting their turn are involved by those currently engaged with the exhibit. The alternative is an exhibit where the visitors standing around disturb those engaged with the exhibit or the visitors, rather than becoming involved by those already engaged with the exhibit, argue over who uses the exhibit next. Exhibitions that have elements of competition create engagement, both among those using the exhibit and among those watching. One should be aware that competition easily reduces the ability of reflection and cognitive learning, but such an exhibition can stimulate the development of physical skills (Rossing, 2016).

8. Relevance (recognition)

In this context, a relevant exhibit means one that creates a certain degree of recognition. It has been shown that when visitors come to a science centre or a museum, they look for something familiar (Falk, 2013, p. 302). It is as if they need a safe harbour before they can begin to explore the unknown. Whatever they encounter in an exhibition need not be identical to what they encounter outside the science centre, only enough that it provides a certain degree of recognition. Thus, they can build new knowledge on the basis of something recognisable. Under this heading, we can also cite an exhibition’s authenticity, i.e. whether it gives a true picture of reality. In museums, this can be about the genuine, original artefact on display. In science centres, it may be that an exhibition is designed so that it ‘strikes a note’ (‘resonates’) with visitors so that their interest is caught. Falk and Dierking talk about an exhibition in harmony with the public’s ‘identity-related needs and desire’ (Falk, 2013, p. 49). In this way, a particular exhibit becomes ‘real’ to them.

9. Affluence (richness)

A ‘rich’ exhibit gives the public the opportunity to manipulate the model in many ways. In addition, use of the exhibit reveals new aspects of the problem so that exploration can take new paths based on a variety of possible stimuli and responses. It is like exploring a cave. The deeper the cave runs and as the numbers of side corridors increase, the more engaging are the explorations. However, it is not enough that there are many roads. The exploration must continually reveal new aspects of the problem while it raises new questions that can be explored by the exhibit. Such an exhibit is ‘rich’ and forms the basis for the visitors’ engagement so that they stay long at the exhibition. Such exhibits have a great ability to keep the audience (‘holding power’). It is also important that this ‘affluence’ is hidden, so that it does not overwhelm the audience but is gradually revealed.

10. Aesthetic and functional

To capture the interest, it is no disadvantage if the exhibit is aesthetically appealing and stands out from the crowd. Just a simple thing like colour has proven to be very important in leading visitors to discover an exhibit and use it. Camilla Magerøy increased the visits to the Gyroscope exhibit by almost 50% just by covering the spokes of the bicycle wheel used with

bright yellow foil (Magerøy, 2012). It is also important, of course, that the model is robust and functional (Allan, 2004).

A final point:

Do not disguise the real subject of an exhibition by activities not intrinsically related to the theme of the exhibition. It is tempting to make the theme of an exhibition exciting by adding an activity or a competition that is entirely irrelevant to the theme. To illustrate how photons hits silicon atoms and excite electrons in a solar panel, visitors might be encouraged to throw balls towards an ‘atom’; if they manage to hit an ‘electron’ with the ball (the ‘photon’); the electron is ‘excited’ and free to move in the circuit. This might make the exhibit very attractive, but it is doubtful whether the visitors will understand more about what happens inside a solar panel.

If we use such tools in an exhibition, the visitors’ activities need to provide skills that support the understanding of the theme that the exhibition wants to convey. This is no easy task and one can understand those who choose ball throwing in such a context, but it is doubtful that such activities support learning about solar cells.

European Exhibition Evaluation Tool (EEET), an evaluation perspective, by Nils Petter

About the EEET project

Main features of the EEET:

- It combines and builds upon the work of the PISEC project (Borun*et al.*, 1997), the MARVEL project presented by Griffin *et al.* (2005) and the VEF presented by Barriault (2010).
- It equalises the importance of different element in the interaction with an exhibit or an exhibition, such as having fun, doing hands-on exploration and discussing the experience.
- It is designed with hardware and software to make it into a time-efficient tool.
- It can be applied to any exhibit that has been designed to convey a specific content or tidings.
- It provides a basis for discussing Exhibit and Exhibition design.

Process evaluation by EEET

Traditional evaluation of a learning sequence is to measure the input and output from the sequence, thus evaluating the result of the learning process. In the EEET, we apply another perspective. Instead of looking at the results of the learning process, we look at the elements of the learning process that are taking place during the visit. Writings of well-recognised pedagogical theoreticians have been used to identify elements and sub-processes that are productive in the process of developing cognitive structures and conceptual understanding. These elements or sub-processes are as follows:

Behaviours for quality evaluation and their rationale in learning theory

Hands-on experience

Piaget describes the educational potential of direct manipulation of objects:

> *[…] physical experiments […] in which knowledge is abstracted from objects, consist in acting upon those objects in order to transform them, in order to dissociate and vary the factors they present […]*(Piaget, 1995, p.714)

Dewey argues that indirect interaction with phenomena can be productive in terms of learning on the condition that the interaction is conscious:

> *[…] senses and muscles are […] external inlets and outlets of the mind.*
> *The boy flying a kite has to keep his eye on the kite, and has to note the various pressures of the string on his hand. His senses are avenues of knowledge not because external facts are 'conveyed' to the brain, but because they are used in doing something with a purpose.*(Dewey, 2011, p.78)

Gardner states that physical manipulation can have relevance for all ages:

> *Some students – old as well as young –learn best with a hands-on approach, dealing directly with the materials that embody the concept.*(Gardner, 2006, p.141)

The positive effect of facilitating physical interaction in exhibit design is discussed by several museum researchers, including Anderson and Lucas (1997), Borun*et al.* (1997), Falk and Dierking (2000) and the Exploratorium APE Team (2005).

To evaluate if hands-on experiences are facilitated, we look for the following behaviours:

H 1. Doing the activity

H 2. Spending time watching others engaged in activity or observing the exhibit

Exploratory Flow experience

Ausubel *et al*. emphasise the importance of being in a positive emotional state while conducting an educational task:

> *[…] motivational and attitudinal variables are not directly involved in the cognitive interactional process. They energise and expedite this process during learning by enhancing effort, attention, and immediate readiness for learning.* (Ausubel *et al.*, 1978, p.405)

Falk and Dierking point to the effect that positive emotions have on memory by quoting Damasio (1994) and Sylwester (1995) and stating that

> *[…] every memory comes with an emotional stamp attached to it. The stronger the emotional value, the more likely sensory information is to […] be admitted into memory; interestingly, pleasant experiences are strongly favoured over unpleasant ones.* (Falk and Dierking, 2000, p.18).

Csíkszentmihályi and Hermanson (1995) developed the concept of 'Flow' to investigate how intrinsic motivation influences the performance of a task and how intrinsic motivation can be facilitated. They state that

> *Flow activities lead to personal growth because, in order to sustain the flow state, skills must increase along with increased challenges. Flow involves the person's entire being and full capacity.*(Csíkszentmihályi and Hermanson, 1995, p.36).

Their statement illustrates the potential of the flow state. However, it also describes the challenge of facilitating this state.Having fun is often described as what we hope for the visitor. We will use the term 'Exploratory Flow' to designate the positive emotional state that exhibition designers often strive to facilitate.To evaluate if Explorative Flow are facilitated we will look for the following behaviours:

F 1. Repeating the activity

F 2. Expressing a positive emotional response in reaction

Development of cognitive structures and conceptual understandings

We will use a model, based on the work of David P. Ausubel (2000), to clarify our view of the critical term 'Learning'. In short, one can say that learning is a change to the cognitive structures of the mind. The cognitive structures can be seen as a cognitive mind map in which the concepts and clusters of concepts are nodes. These concepts or clusters have to be linked together for the structure to be meaningful. This map can also be seen as a web of concepts that, if all concepts are linked, describes meaningful knowledge. The process of making such links or changing the structure to hold new information is an active process. First, one has to analyse the structure to determineif and where the new information fits into the existing structure. Second, one needs to find the significant properties of the new information and use these properties as connectors to the structure or modify the structure to harbour the new information. Third, the new information has to be reformulated into the vocabulary of the learner. Learning means not only incorporating new information but also strengthening the connections of the web and maintaining the links and nodes of the web. The structure can be said to define anchoring points for new learning tasks. For new tasks to be learned, relevant anchoring points have to be present.This tells us that the learning process of developing conceptual understandings is helped if the visitor recognises the content of the exhibit or the presentation of the current phenomenon that the exhibit is displaying.

Facilitation of productive dialogues and discussions is regarded by social constructivism as a significant process in cognitive development. Such social interactions provide for productive interchanges between the inner thoughts of the individual and the outer environment(Vygotsky, 1986). This interchange corresponds to the mental activity that Ausubel (2000) points to as essential for cognitive development.

Engagement in educational activity is important in the process of learning. In their project 'Fostering Active Prolonged Engagement (APE)', the Exploratorium's APE team set up three components that they said were significant for increasing engagement. One of these components was

> *Promotion of self-driven discovery by minimizing instruction and exploration and by encouraging visitor-initiated observation, speculation, play and construction.* (Exploratorium APE team, 2005, p.3)

Several theoreticians have emphasised the importance of self-directed exploring. It is argued that practical discovery helps the process of relating theory to experienced phenomena(Hmelo-Silver, Duncan & Chinn, 2007).

To evaluate if the development of cognitive structures and conceptual understandings are facilitated, we will look for the following behaviours:

D 1. Referring to past experiences while engaging in the activity

D 2. Dialogue regarding intended learning outcomes

D 3. Testing variables, making comparisons, using information gained from activity

Cooperation/Nurturing

Seven of the characteristics that the PISEC project found to improve the learning outcome were related to cooperation (Borunet al., 1997). The research subjects were families, but there are many reasons to suspect that the characteristics also apply to school groups. Borunet al.(1997) found that re-designing the exhibit to enable the family to gather around the exhibit, allowing simultaneous hands-on interaction and fostering group interaction, generated higher performance indicators for the visitors.

Cooperation in groups means that several people have the same experience and similar observations. This promotes the productive dialogues and discussions advocated by social constructivism. To evaluate if cooperation is facilitated, we will look for the following behaviours:

C 1. Working or talking with others

C 2. Helping or explaining to others

Relations between quality related behaviours and codes in EEET software.

The EEET software tool has a number of behavior codes that are used for quality evaluation. Most codes are the related to behaviours that we have argued to facilitate learning. Others are resulting from practical experiences with the tool. How these codes are related to observable behaviours is presented in the following list and table:

<u>List of behaviours categories implemented in the EEET software</u>

H: facilitating Hands-on experience

H 1. Doing the activity
H 2. Spending time watching others engaged in activity

F: facilitating Flow experience

F 1. Repeating the activity
F 2. Expressing a positive emotional response in reaction

D: facilitating Development of cognitive structures

D 1. Referring to past experiences while engaging in the activity
D 2. Dialogue regarding intended learning outcomes
D 3. Testing variables, making comparisons, using information gained from activity

C: facilitating Cooperation

C 1. Working or talking with others
C 2. Helping or explaining to others

U: Unintended experiences (not necessarily negative)

U 1. Unintended use
U 2. Unintended emotions

I: Interruption

I 1. Interruption of exploration

R: handling Roughly or destructively

R 1. Negative handling

Table presenting: <u>Relations between codes in EEET software and quality related behaviours.</u>

Behaviour	Code	Label		Comments
Looking	1	H.2	at exhibit set	
	2	H.2	at Label	
	3	H.2	at additional text	
	4	H.2	looking at screen	
	5	D.2	at worksheets	
	6	H.2	at other visitor doing experiment	
	7	D.3	close-up examination, bending/leaning	
Recording	8	D.3	writing notes, including graphs, schemas, charts, etc.	
	9	D.3	completing worksheet	
	10	D.3	Other drawing	
	11	F.2	taking photos/filming	
Talking	12	D.1	about past experiences	related to the exhibit
	13	H.1	Discussing function of exhibit	
	14	D.3	discussing the science of the exhibit	e.g. Theoretical principles, practical applications
	15	C..2	reading instructions to others	
	16	D.2	reading other information to others	
Handling	17	V.1	playing with exhibit in a way functionally not intended by designer	
	18	I.1	using hands-on exhibits as intended	
	19	C.1	Cooperating	
	20	D.3	Testing variables	
	21	D.2	helping others with hands-on	
	22	I.1	trying to find out how exhibit is working	Until first successful operation of exhibit
	23	F.1	Repeating the activity (exhibit)	After first successful operation of exhibit
	24	R.1	handling roughly, destructively	
Listening	25	I.1	to tape/ to film in exhibit	
	26	I.2	to others directing/explaining function	this could be anyone, e.g. teacher, museum staff or parent
	27	D.2	to others directing/explaining science of exhibit	this could be anyone, e.g. teacher, museum staff or parent
Moving	28	I.1	away from the exhibit	internally motivated, e.g. "finished the experiment"
	29	I.1	Interruption by external force	e.g. teacher calling to leave centre, intercom announcement of show, etc.
Other activities	30	F.2	Displaying indicators of positive emotions	laughing, smiling, whooping, screaming, shouting, expressions of excitement, etc.
	31	U.2	Displaying indicators of not indented emotions	crying, screaming, shouting, stomping, hitting, rude movements, etc.
	32	I.1	Anything that significantly draws attention away from exhibit	Talking about non-related things, pointing to other places/people, etc. IMPORTANT: significant interruption of attention means more than a quick look away or talking to other people
The behaviour list and code system has its origin in the work by Griffin (2005). It is used and modified by Barriault and Pearson (2010) and by the EEET project				

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