EXPERIENTIAL QUALITIES OF SCIENCE MUSEUM EXHIBITS: A THEMATIC ANALYSIS

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Abstract

Designing and supporting the visitor experience with interactive exhibits in science museums is a complex endeavor, particularly because many factors are interrelated and its subjective and dynamic nature. Over the past two decades, a number of studies have addressed this subject from different perspectives. However, the majority of published work addresses only some aspects and most of them are under-articulated. To address this issue, this article attempt to understand how different approaches relate and complement each other. A 'theoretical' thematic analysis was conducted to identify the essential constituent elements of the visitor experience with interactive science museum exhibits. The results of this paper indicate that the visitor, the interactive exhibit, the physical and social context, the engagement process, the learning experience and the science museum purpose are interconnected. Each element is reviewed and defined in detail, delineating its major characteristics.

Keywords: Education, Experience design, Life-long learning, Science museum, Exhibit design

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1 INTRODUCTION

Science Museums are intentionally designed spaces (Bell et al., 2009) where people pursue and develop science interests, engage in science inquiry, and reflect on their experiences through sense-making conversations. Although collecting, preserving or researching are still important activities, the primarily role of science museums has gradually shifted towards a more educative visitor-centered approach (Weil, 1999). Therefore, in recent years, researchers and museum professionals have become increasingly interested in the subjective and dynamic nature of the visitor learning experience (Falk and Dierking, 2012) where interactive museum exhibits plays an essential role (Dillenburg, 2011).

Interactive museum exhibits are a vital component in sustaining the institutional image and expanding the popularity of museums (Falk et al., 2004). McLean (1993, p. 93) defines interactive exhibits as "those in which visitors can conduct activities, gather evidence, select options, form conclusions, test skills, provide input, and actually alter a situation based on input". Interactive exhibits are effective tools that enable visitors to actively engage on an intellectual, physical, social and emotional level (Perry, 2012) and offer opportunities for visitors to learn through experience (Ansbacher, 1999).

Over the past 20 years, a number of studies have addressed the visitor experience with interactive museum exhibits from different perspectives. These include contributions from psychology, museum studies, informal science education, human factors, HCI and other disciplines. Each approach has helped to understand the richness and nuances of the visitor learning experience when interacting with museum exhibits, but also has made clear that designing and shaping experiences of others is a hard and multifaceted endeavor. According to Beghetto (2014) "exhibit designers are, in a fundamental way, charged with this complex and seemingly untenable task".

Although there is evidence that support the idea that the quality of the learning experience is directly related to the experiential qualities of the interactive museum exhibit (Allen and Gutwill, 2004; Allen, 2004; Falk et al., 2004), it remains unclear what one need to consider when designing or evaluating them. The majority of practical or conceptual contributions that were studied addressed only some aspects of the visitor experience, often evidencing certain disciplinary biases (Kirchberg and Tröndle, 2012), and most of them were under-articulated (McCarthy and Ciolfi, 2008). Consequently, the fragmentation across diverse knowledge domains has slowed the consolidation of both theory and practice (Roberts, 2014). In relation to the latter, McDonald (2007) argued that too often exhibitions are created with little awareness of such contributions leaving the museums to rely only on observations from their own institution. As a result, most of the design decisions are based on intuition or tacit knowledge (Yellis, 2010) and therefore exhibit designers are limited to make informed decisions that might enhance exhibition experiences (Falk et al., 2004). The consequences of this are evident when visitors find exhibits unattractive, boring, frustrating or confusing; hence, museums lose the opportunity to engage their visitors into meaningful learning experiences.

According to the problems that were mentioned above, the purpose of the present study is to analyse and integrate previous studies in order to identify essential elements of the visitor experience with an interactive science museum exhibits. This work makes part of an ongoing research project that aims to develop a set of design heuristics that will help exhibit designers to take informed decisions when designing or evaluating the experiential qualities of an interactive exhibit, particularly in the beginning stages of concept development and prototype design as advocated by Adams (2004). In this manner, the Section 2 aims to describe the method applied in the study. Section 3 describes the results of the analysis. Section 4 presents the conclusions and proposes future work.

2 METHODOLOGY

There are two different ways to analyse qualitative data in order to identify the essential elements of the visitor experience with an interactive exhibit: manually or computationally. Today many mining data software are available, such as *Semantria* or *Qiqqa* that use algorithms to develop themes, categories and relationships between entities. These emerging and technological methods are promising but not very reliable yet. On the other hand, Thematic analysis (TA) is a widely used qualitative method. TA is structured and clearly defined (Ariza and Maya, 2014); provides a flexible, domain independent research tool, which can potentially provide a rich and detailed account of data. According to Braun and Clarke (2006), this method is used for identifying, analysing and reporting patterns within data; it organizes and describes the data set in detail and can usefully summarize key features of a large body of data, highlights similarities and differences across the data set and it is possible to generate unanticipated insights. Consequently, the TA method was chosen for identifying and defining the essential elements of the visitor experience with interactive science museum exhibits. Following this, the methodology applied in this work is described in Figure 1.

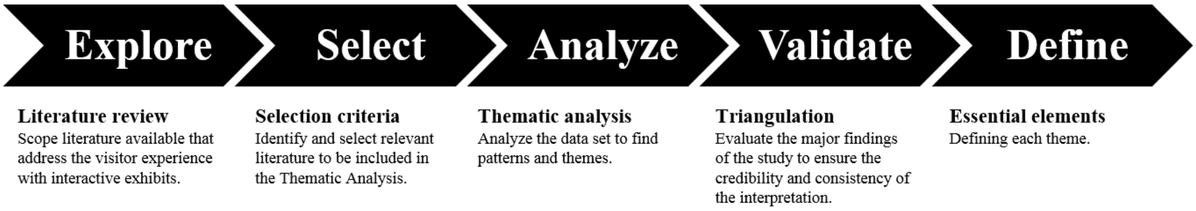

Figure 1. Stages of the methodology

2.1 Literature review

Since the field of study of interactive museum exhibits is fragmented and under-articulated the challenge was greater to develop a literature review. First, a research question was formulated: What are the essential elements of the visitor experience with interactive exhibits? The search process was performed manually. It started with the consultation of seminal contributions (i.e. Allen, 2004; Falk, 2009; Humphrey et al., 2005), which then were expanded by looking at the references cited. Two major journals were identified in the field of museums, which were reviewed manually: “Museum Management and Curatorship" and "Curator: The Museum Journal”. The search methods were adjusted to the specific requirements of the different electronic libraries. Furthermore, digital libraries and search engines were used for collecting information, using these search keywords: interactive exhibit, visitor experience, learning, science museum. Electronic sources and digital libraries relevant to the research were used, such as ACM Digital library, Google Scholar, ScienceDirect, Taylor & Francis, Wiley, Emerald and Springer Link.

2.2 Selection criteria

The purpose at this stage was to identify key issues that museum researchers have pointed out as being relevant for the understanding of the exhibit visitor experience. The selected literature had to fulfil the following criteria: (a) peer reviewed studies; (b) published from 1995 to 2015; (c) journal and conference papers, books and book chapters; in contrast, workshop, panel, tutorial, seminar and posters were not included; (d) written in English; (e) direct relationship of the study with the research question: ¿What are the essential elements of the visitor experience with interactive exhibits?.

2.3 Thematic analysis, TA

TA involves a number of choices that need to be explicitly considered and discussed before conducting the analysis of the data (Braun and Clarke, 2006). First, themes or patterns within data can be identified in one of two mainly ways, whether taking an inductive or theoretical approach on the TA. Given the nature and purpose of this research a ‘theoretical’ TA was chosen. In this regard, the analysis was driven by the researcher’s interest in the area and codes were framed within a specific research question. Another decision had to do with the level at which the themes were to be identified. Themes were identified within the explicit or surface meanings. In that sense, the analysis process involved a development from description, where the data was organized and summarized to find patterns within the semantic content, to interpretation, which attempted to theorize the importance of the patterns and their broader meanings and implications in relation to previous literature (Braun and Clarke, 2006).
The thematic Analysis process involves the searching across a data set to find repeated patterns of meaning. It starts when the researcher is looking for those patterns and ends with the report of the content and meaning of themes in the data set. Braun and Clarke (2006) provide an outline guide comprised by six phases of analysis as follows: (1) familiarizing yourself with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes (5) defining and naming themes and (6) producing the report.

3 RESULTS

3.1 Literature review and selection criteria

From the search results and after applying the selection criteria, 83 publications were found relevant to the current analysis. Due to the high amount of data, the variety of contributions and the qualitative nature of the TA, it was necessary to reduce the number of papers for the analysis. When selecting the final literature it was important to capture and balance different disciplines and approaches and to determine whether they were successful in describing experiential elements. Finally, 28 contributions were selected as part of the theoretical framework that would support the analysis and definition of the essential elements of the visitor experience with interactive exhibits.

3.2 Thematic analysis

The TA process started by organizing the information on a general level before generating initial codes. When reviewing the literature, a number of models and theoretical approaches were found. These approaches were clustered into four lenses, namely exhibit-lens, visitor-lens, process-lens and outcome-lens. *Exhibit-lens* approaches provide guidelines and explore exhibit attributes and issues that need to be considered when designing or evaluating interactive exhibits, for example interactivity issues (Allen and Gutwill, 2004). *Visitor-lens* approaches focus their attention into the experience preferences (Pekarik et al. 2014), intrinsic motivation (Perry, 2012; Packer, 2004; Csikszentmihalyi and Hermason, 1995) or identity-related needs (Falk, 2009). The *Process-lens* approaches help to understand what visitors do while interacting with exhibits; contributions in this perspective are related with attention (Bitgood, 2010) or engagement (Barriault, 2014; Humphrey et al., 2005) (Haywood and Cairns, 2006). Finally, the *Outcome-lens* explore what visitors take away from the learning experience in terms of knowledge, attitudes, skills, among others (Falk et al., 2004) (Ansbacher, 2002a). Taken into consideration the four different approaches, the entire data set was categorized in Table 1.

Table 1. Preliminary categorization of the data set

Perspective	Publications
Exhibit lens	(Adams et al. 2004), (Allen, 2004), (Latham, 2007), (McCarthy and Ciolfi, 2008), (Witcomb, 2006) (Gilbert and Stocklmayer, 2001)
Outcome lens	(Ansbacher, 2002a), (Falk et al. 2004), (Rahm, 2004), (Soren, 2009)
Process lens	(Packer, 2006), (Meisner et al. 2007), (Ansbacher, 2002b), (Ansbacher, 1999), (Barriault, 2014), (Haywood and Cairns, 2006), (Hennes, 2002), (Humphrey et al. 2005), (Meredith et al. 1997), (Paris, 1997)
Visitor lens	(Packer, 2004), (Bitgood, 2010), (Csikszentmihalyi and Hermason, 1995), (Pekarik et al. 2014), (Pekarik et al. 1999), (Falk, 2009), (Perry, 2012)

After identifying and grouping different approaches, the coding process started. A number of 388 notes were extracted and 1004 initial codes were generated. Table 2 shows an example of the construction of initial codes that was applied to a data extract taken from Allen (2004).

Table 2. Codification example

Data extract	Codes
Science museum staff face a constructivist dilemma as they design their public spaces: the exhibits should facilitate science learning, yet they also need to support a diverse visiting public in making their own personal choices about where to attend, what to do, and how to interpret their interactions. To be effective as teaching tools, exhibits need to be highly intrinsically motivating at every step of an interaction in order to sustain involvement by an audience who views their visit primarily as a leisure activity.	Constructivism Personal choice Teaching tool Intrinsic motivation Interaction Sustained involvement Leisure activity

Then all the different codes were organized and grouped into potential themes. See an example in Table 3. The process ended up with a collection of 11 preliminary themes and more than 50 subthemes (See Table 4). At this phase it was evident the richness and complexity of the theming process. The challenge then was to refine and validate the preliminary themes in order to identify the essential constituent elements.

Table 3. Grouping codes example

Grouping codes	Codes
Fun and enjoyment	Joy, fascination, enjoyment, fun, excitement Enthusiasm, playful experience, entertainment, deep enjoyment
Involvement	Involvement, mental effort, deep concentration Sustained involvement, perception of time - loss in time, loss of time and place, persistence, intrinsic motivation, unaware of fatigue, flow

Table 4. Example of potential themes

Potential themes	
Personal context	Learning Experience
Physical Context	Disengagement
Social Context	Learning experience outcomes
Exhibit Dimensions	Inquiry Cycle
Engagement channels	Interaction Cycle

3.3 Validation

One important step in the TA is that the preliminary themes need to be evaluated to ensure they represent the whole of the text (Alhojailan, 2012). A triangulation process was implemented aiming to integrate multiple methods in order to offset researcher biases, evaluate the major findings of the theming process to ensure the credibility and consistency of the interpretation (Jonsen and Jehn, 2009). A quantitative approach was taken to the entire data extract using KH Coder, a content analysis software. In order to identify patterns across the data set as well as relationships between concepts a co-occurrence network (CON) was employed. A CON show words with similar appearance patterns connected with lines. The size of the circle represents each word according to the appearance frequency of the words (See Figure 2).

A co-occurrence network provided a graphic visualization of potential relationships between the main subjects associated with the visitor experience with interactive museum exhibits. The results of CON, complemented with a word frequency list, suggested that the data extract was primarily related to *experience* (TF=418), *visitor* (TF=299), *exhibit* (TF=263), *learning* (TF=213), *museum* (TF=193), *engagement* (TF=113), *attention* (TF=84), *science* (TF=65) and *time* (TF=63). The CON analysis helped to review and refine the potential themes identified previously, as well as highlight strong concepts that where missed in the theming process such as time or science museum. During this phase, some themes were discarded since there were not enough data to support them, while others were collapsed into each other. Taken together the CON analysis as well as the potential themes identified previously it was possible to integrate and reduce the entire data set into 7 main themes and 18 subthemes. The results shown in Table 5 are the essential elements resulting from the analysis.

3.4 The experiential qualities of science museum exhibits

This section presents and defines the constituent elements of the visitor experience with interactive exhibits presented in Table 5. It was necessary to complement the information derived from the analysis by using related contributions from the literature review.

The visitor: the visitor experience with interactive exhibits is highly idiosyncratic, and therefore, without a visitor no exhibit experience would exist. Roberts (2014) argues that designers design for experience and not create experiences, since the act of meaning making finally belongs to the visitor. In that manner, the visitor experience is strongly influenced by his or her *prior knowledge and experiences* (Ansbacher, 1999; Roschelle, 1997); and *interests and motivations* (Falk, 2009; Csikszentmihalyi and Hermason, 1995; Perry, 2012). The entering motivations, the engagement, and subsequent learning are not separate aspects of the visitor experience but rather highly correlated (Falk, 2009).

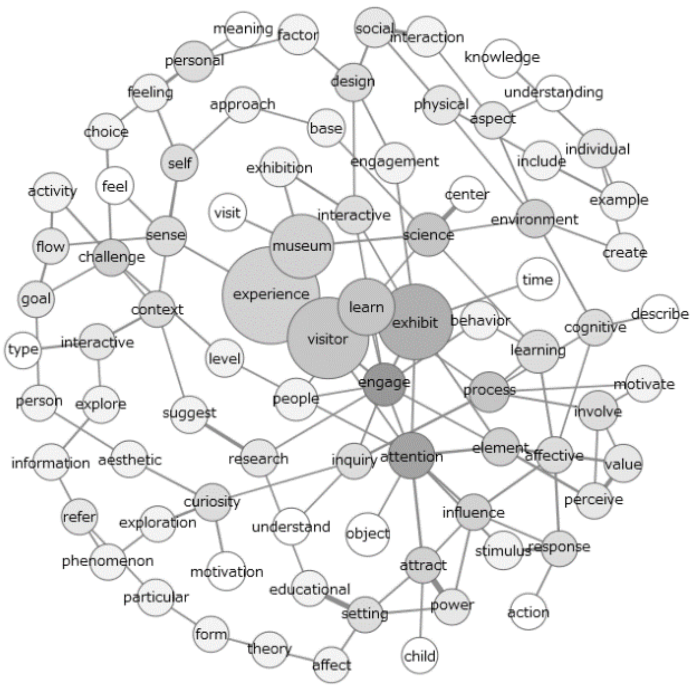

Figure 2. Co-occurrence network of the data extract

Table 5. Themes and sub-themes of the visitor experience with interactive museum exhibits

Themes	Subthemes
The Visitor	Interests/ motivations - Prior experience / prior knowledge.
The Physical Context	Environmental conditions - Exhibition configuration - Exhibit location.
The Social Context	Crowd conditions - Social mediation - Group composition.
The Interactive Exhibit	Content and information - Media and technology – Interactivity.
The Engagement Process	Engagement cycle - Affective response - Behavioral response.
The Learning Experience	Learning outcomes – Learning attributes.
The Science Museum Purpose	Educational purpose - design intentions

The physical context: learning always occurs when interacting with the physical environment (Falk and Storksdieck, 2005). There are a number of *environmental conditions* that affect the way people engage and experience exhibits such as temperature, light, colour and sound conditions. The *exhibition configuration* is also relevant since visitors need to navigate freely through space while feeling oriented and secure. When people feel disoriented, it directly affects their ability to engage with exhibits (Falk and Dierking, 2012). The *location of the exhibit* influences the degree and quality of visitor engagement; for example, Adams, Luke and Moussouri (2004) argue that exhibits that are placed near the entrance to an exhibition attract the attention of more visitors. In general, designing for engaging visitor experiences has to address the whole environment where the interaction occurs, not only the exhibits or technology (McCarthy and Ciolfi, 2008).

The social context: museums are highly social spaces where people gather, share and participate in different activities and experiences. *Crowd conditions or crowd size* are important factors in the quality and quantity of visitor engagement (Adams et al., 2004). For instance, if the exhibition is crowded, then visitors will most likely spend less time interacting with exhibits. *Social mediation* is the social interaction facilitated by museum staff, often referred as explainers or volunteers. Explainers welcome, facilitate and encourage visitors to be actively engaged in activities (Kamolpattana et al., 2015). Finally, the *group composition* of the visit influence the nature and quality of the learning experience. Most visitors go to museums in social groups consisting of family and friends. All social groups in museums interact to each other in a way reinforcing shared beliefs, interpreting information, for meaning making. (Falk and Storksdieck, 2005).

The interactive exhibit: an interactive exhibit is a pedagogical device (Witcomb, 2006) placed within a museum exhibition that integrates *content and information, media and technology* into an interactive system that engages visitors in science learning experiences (Bell et al., 2009). In this way, *interactivity* is considered as an intrinsic quality of the exhibit, comprised by a set of attributes, which affords and stimulates the visitor engagement (Ocampo A, 2014). These elements are grouped into three types of interactivity: *physical, social and mental* (See Table 6).

Table 6. Description of the different types of Interactivity

Type	Description	Interactive attributes
Physical	All the various ways in which the exhibit encourage visitors to interact with their body and their senses. Often referred to as hands-on exhibits.	Corporality, physicality, sensory stimuli, immersion, construction.
Social	All the various ways in which the exhibit stimulates visitors to engage with one another socially. Often referred to as participatory exhibits.	Collaboration, companionship, conversation, guidance.
Mental	All cognitive and intellectual processes that are triggered by the exhibit. Often referred to as minds-on interactivity.	Choice, control, goals/rules, feedback, challenge/conflict, uncertainty, novelty, apprehendability, fantasy, exploration/ discovery, novelty, completion, creation, identification, aesthetic appeal.

The Engagement process: engagement is the heart of the whole exhibit experience and becomes a primary tool for both developing exhibits and evaluating their success (Ansbacher, 2002b). A number of studies suggests that the level to which each visitor is engaged by an exhibit is a direct indicator of the learning taking place (Barriault and Pearson, 2010; Bell et al., 2009; Haywood and Cairns, 2006). The engagement process consists of all the behavioral and affective responses that result from the interaction with exhibits and other people through time and space.
The engagement cycle describes the spatiotemporal nature of the interaction at different stages: attraction, initial engagement, deep engagement and disengagement. An engaging exhibit must attract and hold the attention of the visitor, have a clear and attractive entry point and encourage prolonged interaction (Hein, 2006a; Humphrey et al., 2005). In that way, the amount of time that visitors spend in an exhibit can be also an indicator of learning (Serrell, 1997). *Disengagement* can occur for intrinsic reasons (i.e., task completion, fatigue, negative affect) or extrinsic reasons (i.e., distractions, agenda).
When interacting with engaging exhibits the visitor make subjective judgments that result in feelings of pleasure and enjoyment; involvement; curiosity and interest; confidence and competence; personal meaning and relatedness. These *affective responses* lead to an intrinsically motivated visitor (Csikszentmihalyi and Hermason, 1995) and will depend highly on both what the exhibit affords (i.e., interactive attributes) and the visitor prior knowledge, interests and motivational needs.
The *behavioral response* consists of all the actions performed by the visitor when interacting with exhibits such as questioning, observing, reasoning, playing, predicting or manipulating that are often referred as learning behaviors (Barriault, 2014) or inquiry behaviors (Bell et al., 2009).

The learning experience: learning in science museums is different from learning in any other setting because of the unique and informal nature of the museum context (Falk and Storksdieck, 2005). Evaluating the learning experience in science museums needs not only focus on cognitive gains, but also the conditions and the engagement that lead to learning (Barriault and Pearson, 2010). Therefore, learning through the use of interactive exhibits is characterized by the following *attributes*: active process, self-directed, autotelic, dialogical, holistic, contextual, subjective, dynamic and unique.
Learning is a process of transformation of schemas (Hein, 2002) and therefore for a successful museum visit, visitors must be changed in some way (Perry, 1993). Packer (2006) found that visitors value

learning in museums because it is a potentially transformative experience. In that manner, interactive exhibits play an essential role in facilitating a range of visitor *learning outcomes* (Falk et al., 2004). Within the context of this analysis, four outcomes emerged to be relevant from museum experiences: meaning, attitudes and motivation, identity, and skills. When designing exhibits Perry (2012) argues that it is important to consider both engagements (process) and outcomes since they are essential and intertwined elements of the museum visit. Similarly, Ansbacher (2002a) suggests that exhibit developers must not only have outcome goals as well as process goals, they must be able to show the connection between the two.

The science museum purpose: science museums are public institutions that are *intentionally designed* for learning about science and the physical and natural world (Bell et al., 2009). Therefore, every museum exhibit reflects the intended communicative and pedagogical goals of designers and educators. For example, Witcomb (2006) related interactives with educational theories developed by Hein (2002), such as didactic expository, stimulus – response, discovery and constructivist exhibits. However, it is now widely understood within the science museum community that learning is a complex, contextual, participatory, experiential and visitor-centered process that involves more than just acquisition of facts and concepts. For that reason, contemporary science museums are increasingly adopting a more socio-cultural and constructivist view of learning (Hein, 2006b; Falk and Dierking, 2012; Allen, 2004; Bell et al., 2009). Consequently, the *educational purpose* as well as all the *design intentions* would eventually shape the way the interactive exhibit is materialized and influence how learning is experienced (Beghetto, 2014; Adams et al., 2004).

4 CONCLUSIONS AND FUTURE DIRECTIONS

The visitor experience with interactives exhibits is a complex phenomenon; particularly because many factors are interrelated and its subjective and dynamic nature. Over the past two decades, many efforts have been done for increasing the understanding of this multifaceted and rich subject. This study, attempted to comprehend how different approaches related and complemented each other. In order to identify the essential elements of the visitor experience with science museum exhibits the Thematic Analysis demonstrated to be a valuable method for finding patterns across different perspectives, researchers and disciplines. The results of this paper indicate that the visitor, the interactive exhibit, the physical and social context, the engagement process, the learning experience and the science museum purpose are interconnected. The main contribution of this analysis is the broad perspective that it offers for studying and designing interactive exhibits that facilitate engaging learning experiences for visitors in science museums.

This work has identified the building blocks of what would eventually lead to the development of a more comprehensive framework of the visitor experience with interactive science museum exhibits, since not all the elements were researched to the same extent. Additionally, based on this framework, the ongoing research attempts to develop a set of design heuristics that would help exhibit designers to support their decision making process for the design and evaluation of the experiential qualities of interactive museum exhibits, particularly early in the development process. Furthermore, the design heuristics will contribute to bridge the gap between visitor experience research and exhibit design practice as advocated by McDonald (2007). This endeavour is primarily intended for those science museums with no specialized personnel, limited financial resources and short development timelines that are committed to create transformative exhibits that engage visitor's mind, body and heart.

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