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ORIGINAL PAPER

Museums as avenues of learning for children: a decade of research

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Abstract In this review, we focus on the museum activities and strategies that encourage and support children's learning. In order to provide insight into what is known about children's learning in museums, we examined study content, methodology and the resultant knowledge from the last decade of research. Because interactivity is increasingly seen as essential in children's learning experiences in a museum context, we developed a framework that distinguishes between three main interactivity types for facilitating strategies and activities in children's learning: child–adults/peers; child–technology and child–environment. We identify the most promising strategies and activities for boosting children's learning as situated in overlapping areas of these interactivity types. Specifically, we identify scaffolding as a key to enhanced museum learning. Our review concludes by highlighting research challenges from the last decade and recommendations for practice and future research on how to design, evaluate and guide theoretically-grounded educational programs for children in museums.

Keywords Facilitating strategies and activities · Informal learning · Museum education · Review

Introduction

"A museum is an educational country fair" (Semper 1990, p. 50) that is rich with exciting things for individuals to explore and discover through touch and inquiry. Museums direct learning by providing visitors with unique opportunities to explore various concepts of

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mathematics, art and social science. As with museum education experts (e.g. Falk and Dierking 2000; Falk and Storksdieck 2005; Hooper-Greenhill and Moussouri 2000; Kelly 2007), we recognise the need for a conceptual change from museums as places of education to places for learning. By responding to the needs and interests of visitors, we believe that museums can transform from “being about something to being for somebody” (Weil 1999, p. 229).

Children’s learning takes place in a range of formal (i.e. traditional classroom) and informal settings (e.g. unstructured and self-paced museum program; Falk and Dierking 2000). Generally, learning in museums and other non-school-based environments is referred to as informal or free-choice learning and is qualitatively different learning from that in schools (Falk and Dierking 2000). As a result, findings from research in school-based settings are not easily transferable to museums because learning in museums operates in rich and complex sites and focuses on concrete material such as objects and exhibits (Hooper-Greenhill and Moussouri 2000).

Although the last three decades of museum research have resulted in significant findings and advances, there are many knowledge gaps about learning in museums. For example, the importance of visitor’s personal context (motivation and experience), social interaction and the museum context are highlighted as important factors in museum learning and meaning making (e.g. Falk and Dierking 2000). However, we know very little about children’s learning processes and results from experiences in different museum types, and how their learning can be best guided. Moreover, there is a need to map the appropriate research approaches that would facilitate this goal.

For the purpose of this review, we define museums as informal learning environments as accessible by the public, based on the subjects of science, history, archeology and arts, and involving various objects and exhibits (live and/or simulated) and programs. Consequently, we refer to various types of museum such as: science museums and centres, children’s museums, history and archaeology museums, and art museums/galleries. Interactivity is a focus of this review because it is increasingly seen as essential in children’s learning experiences in a museum context (e.g. Cheng et al. 2011; Falk and Storksdieck 2005). That is, learning is seen as embedded in the interactive process between children and knowledgeable ones, and media at hand, which makes children’s museum learning both dialogical and hands-on (Henderson and Atencio 2007).

Audiences of various ages, including children, visit museums. A bibliographic review by Hooper-Greenhill and Moussouri (2000) focused on a decade (1990–1999) of general museum learning research and highlighted how children’s museum learning was mainly studied in the context of science museums in the United States. Very little was revealed about children’s learning in history and archaeology museums or art galleries, and in other countries. The majority of research in science museums concentrated on exhibits, while learning through participation in educational programs or while using educational materials was scarce. Most of the studies reviewed by Hooper-Greenhill and Moussouri used a positivistic approach to learning with an emphasis on testing hypotheses.

Research on child-focused museum programs primarily aimed to understand children’s learning from a theoretical base, used a combination of qualitative and quantitative methods, and placed learning within the sociocultural context. The effect of interactions with adults on children’s museum experience was highlighted with attention to adult scaffolding as particularly supportive of children’s learning. Overall, Hooper-Greenhill and

Moussouri (2000) identified a need for more research into children's learning across various types of museums. Also, they made a plea for research that makes the study design transparent, by clearly describing the process of museum learning, and how it is the same as or different from learning processes in other sites.

Children represent one of the major museum visitor groups and not just in children's museums. For example, in the United States, about 80 % of museums provide educational programs for children (Bowers 2012) and spend more than $2 billion a year on education activities (American Alliance of Museums 2009). Although a surprisingly-high number of museums offer educational programs for children, there is no review focusing mainly on children's learning within museums. In particular, very little is known about preschool and elementary school-aged children learning in museums. In order to create museum environments that are conducive to children's learning, there is a growing desire for museum professionals and researchers in museum education to know more about children's learning in museums. To move this process forward, there is a need to form a foundation based on previous research efforts, identify issues and present directions for future research on children's museum learning.

This review is, to the best of our knowledge, the first that covers both theoretical and empirical studies about children's learning in various museums types in the last decade (1999–2012) and across countries. Based on the identified gaps in the research, an agenda for future research into children's learning in museums is offered. The review is scientifically relevant in two ways: (a) it provides an overview of learning theories and methodologies for studying learning in museums, which can be used by museum researchers and for other informal learning studies and (b) it develops a framework of facilitating strategies and activities for children's learning in museums. We conclude with practical implications that offer a foundation for museum professionals in designing theoretically-grounded and effective educational programs for this target group of visitors, and help museum educators, teachers and families to facilitate children's learning in various types of museums.

The overall aim of our review is to provide insight into what is known about children's learning in museums worldwide over the last decade, while focusing on how learning can best be facilitated. Specifically, we aim to identify *what* has been studied, *how* children's learning in museum has been studied and what *knowledge* this research has yielded. We focused the analysis of *what* has been studied about the strategies and activities aimed at facilitating children's learning in museums. Specified questions were aimed at distinguishing the *what* (e.g. different strategies and activities) and *how* of children's learning in museums. First, however, we want to characterise the research in terms of learning theories that inform the research on children's learning in museums and the methodological approaches used. By mapping the well-recognised learning theories and research methods, we aim to prepare the ground for further research improvements. To this end, we posed the following research questions:

1. Which learning theories informed the research?
2. Which methodological approaches were applied?
3. Who and what were facilitating the learning?
4. Which activities and strategies were used to facilitate children's learning?
5. What knowledge has the research yielded about children's learning in museums?

Method

Article selection

We performed the literature search for related articles in February 2012. We initially searched the database of the Web of Science for peer-reviewed theoretical and empirical articles published between 1999 and 2012 and relevant to children's learning in museums. The reason for starting the search in 1999 was that a comprehensive bibliographic review of research on this topic until 1999 is available (Hooper-Greenhill and Moussouri 2000). Articles were included if they were: (a) written in English; (b) published between 1999 and 2012; (c) provided a definition or description of learning in museums within the theoretical, methodological or results sections and (d) focused on preschool or elementary-school visitors under 12 years old (identified as the general age for the start of high school in most of the study populations). We excluded articles on visitors of high-school age because younger children's museum experiences can be qualitatively different and depend on their development of abstract-level thinking/operations (Van Schijndel et al. 2010). We also excluded articles from our review if the focus was on museum curators' learning or training programs and if articles lacked a clearly-stated theoretical and/or methodological approach. However, because the museum field is developing, in a few cases, we decided to include resources that did not completely match our inclusion criteria, because they could help to answer our research questions.

Procedure

Our five-step review procedure is summarised in Table 1. Step 1 involved a search of the Web of Science database. Step 2 focused on two leading journals on research and theory in museum education (*Curator: The Museum Journal* and *Journal of Museum Education*). In Step 3, we examined the results of 264 studies, with 33 deemed to be relevant to this review. Step 4 involved a concurrent search during which we compiled an additional eight articles from leading researchers in the field of museum education, our review of 33 reference lists, and familiar empirical research. Lastly, Step 5 centred on identifying key resources. In total, our review was based on 44 sources (identified in the reference list with an asterisk): 41 peer-reviewed articles, a review (Hooper-Greenhill and Moussouri 2000), a doctoral dissertation (Kelly 2007), and a book (Falk and Dierking 2000). Of the selected

Table 1 Article selection procedure

Step	Description	Results
1	Searched electronic database Web of Science by title with the combination of key words (e.g. learning, museum, children)	151
2	Searched two journals	113*
3	Examined 264 studies	33
4	Concurrent (with steps 1 through 3) search of leading researchers in the field of museum education, our review of reference lists, and familiar empirical research	8
5	Inclusion of key resources	3
Total sources included for review		44

* 17 in Curator: The Museum Journal and 96 in Journal of Museum Education

articles, we identified articles that were written by the same author/coauthor more than once: Falk (3), Piscitelli (2), Tenenbaum (2) and Weier (2).

Analysis strategy

Our analysis of the 44 sources involved three subsequent rounds. First, we examined the articles in order to develop a general profile of the research on children's museum learning. This round of analysis was also aimed at identifying the main learning theories (research question 1) and methodological approaches (research question 2) used in research on children's museum learning. Our interpretations of the theories and/or the methodologies applied in empirical studies were guided by Hooper-Greenhill and Moussouri (2000) and the reviewed theoretical papers. The second round of analysis sought to answer research questions 3 and 4 while contributing to the development of a framework of facilitating strategies and activities. This framework was further developed during several discussions between the first and the third author after a first reading of the articles. We present our framework in the methods section (under Analysis scheme), as it was used to analyse the literature in the third round of analysis and to organise the main part of the review (research questions 3, 4 and 5). In the third round of analysis, the first author used the framework to code the articles. Also the other columns of Table 3 in Appendix were filled. The second author checked the coding and Table 3 for unclear aspects and inconsistencies. If necessary, the original articles were consulted, and Table 3 was complemented or changed. The second author critically reviewed the interpretations as presented in the text.

Analysis scheme

The highlighted value and different forms of interactivity (as the core of a learner's museum experience) guided our framework development. In fact, interactivity became the focus for our unit of analysis (facilitating strategies and activities in children's museum learning). It is important to note that, within our framework, we refer to facilitating strategy in a much broader sense than activity. That is, while the latter presents a specific and single activity type or task (e.g. to tell a story), the former comprises a structured or semi-structured combination of different activities (e.g. hands-on, story-telling, explanation) that have a shared learning goal. Table 2 presents the seven descriptors that we used when coding facilitating strategies and activities. Figure 1 displays an illustration of our framework in which we distinguish between three main interactivity types (coded 1 to 3) and four that share qualities of the main types (coded 4 to 7).

Results

In this section, we present an overall profile of the reviewed resources, theoretical perspectives, methodological approaches and information sources used, as well as results based on applying our framework for children's learning in museums. Because research context has a major effect on the way in which learning is conceived and on the research methodologies chosen (Hooper-Greenhill and Moussouri 2000), we present our findings according to type of museum: science museums and centres, children's museums, natural history museums, and art museums/galleries. (In cases for which the research encompassed more than one museum type, we grouped the research within the science museums and

Table 2 Framework descriptors for facilitating strategies and activities in children's learning in museums

Code	Label	Description
1	Child–adults/peers interaction	When children's learning is guided exclusively by humans—the knowledgeable adult (museum educator, teacher, parent) or peer, through their conversational interactions: telling stories, asking questions, explaining
2	Child–technology interaction	When network technology applications are deployed in guiding children's learning in the museum learning environment (computer and mobile phone tasks and games)
3	Child–environment interaction	When children interact with objects from the museum environment (e.g. hands-on activities, worksheets, free play, free-choice activities and free explorations)
4	Child–environment–adults/peers	When children's interaction with the environment is guided with child–adults/peers (e.g. guided play, exploration and hands-on activities
5	Child–technology–adults/peers	When children's engagement with the technology is guided by the knowledgeable adult/peer
6	Child–technology–environment	When children, guided by the technology, interact with the museum environment (e.g. exploration, worksheets tasks, hands-on activities)
7	Total interactivity	Strategies and activities that imply the combination of all the above stated interactivity types

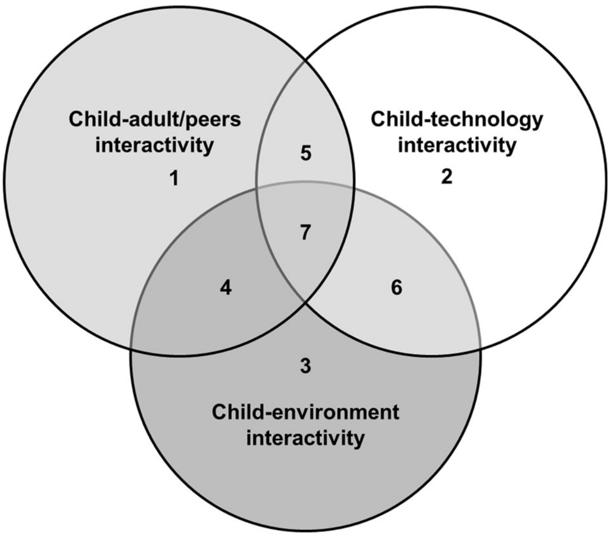

Fig. 1 The framework of facilitating strategies and activities in children's learning in museums

centre type, as this was the most common type.) Findings are presented in narratives and augmented with examples. Table 3 in Appendix presents a systematic overview of the reviewed empirical studies along with methodological characteristics and study design.

Profile of the research

As displayed through Fig. 2, our review revealed children's learning in museums as being researched primarily in science museums and centres, followed by history museums (especially natural history museums)—adding up two thirds of the research. In contrast, very few research studies were conducted within children's and art museums and galleries. The majority of study participants were children older than six years, with much research focusing on 9-years-old and elementary-school students (52.28 %). Out of 44 studies, about half (47.72 %) focused on children (under 9 years old) and took place in Australian and American museums (e.g. Anderson et al. 2002; Mallos 2012). About two-thirds of the studies reviewed focused on field-trip visits to museums from schools, with less of an emphasis on family learning. However, interactions within parent–child dialogues during a family visit and within whole-class and small-group settings were the focus of the majority of the studies, with peer dialogue interactions studied at a slightly lesser extent (see Table 3 in Appendix). A somewhat surprising finding was how few studies examined children's exploratory behaviour while learning during a museum program or exhibit.

Of the 44 articles, more than half were conducted in the US (59.09 %), with the remainder spanning a range of locations (13.63 % in Australia, 9.09 % in the UK, 9.09 % in Europe, 6.81 % in Asia and 2.27 % in Canada). The majority of the research was empirical (31 articles) and cited descriptive or exploratory case studies and surveys (with the exception of one ethnographic study). As well, two action-research studies and 13 experimental studies were included (see "Appendix"). The remaining articles were categorised as theoretical (12 resources) or a review (1 article). Most of the descriptive research depicted learning activities, interactive exhibitions, conversations with museum educators or parents and peers (and the roles that they take), as well as children's

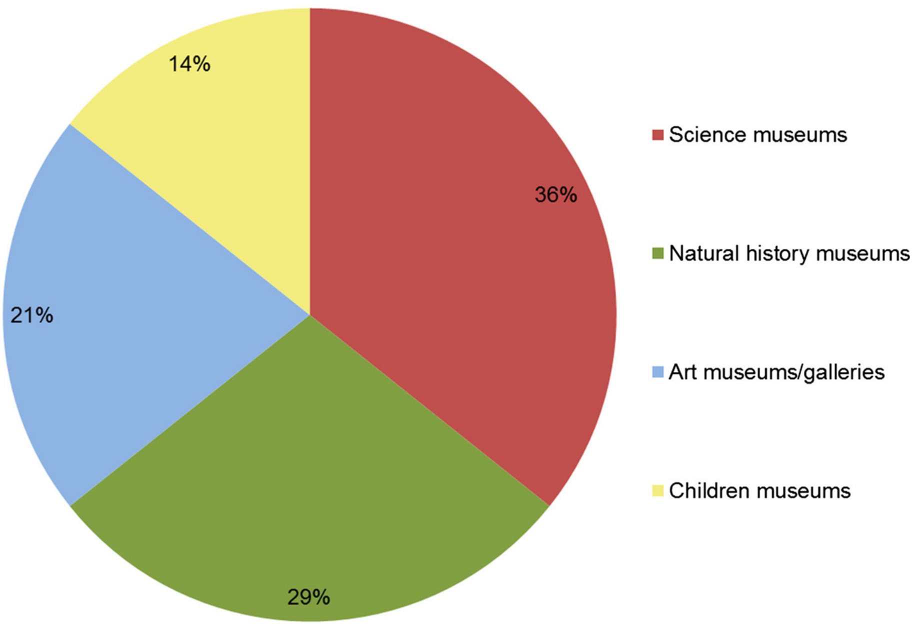

Fig. 2 Percentage of total 44 reviewed sources presented per museum type

interactions and learning experiences with the exhibit or with objects in museums. Most of the theoretical studies (27.27 %) focused on the conceptualisation of the nature of learning in museums (Falk 2004; Falk and Dierking 2000; Falk and Storksdieck 2005), characteristics of learning in museums (e.g. Rennie and Johnston 2004) and the design of the research in learning in museums (e.g. Reisman 2008).

Theoretical perspectives

In the last decade, constructivism and, in particular, sociocultural theory have greatly impacted children's programs/exhibition and museum learning research designs (Bamberger and Tal 2007; Falk and Storksdieck 2005; Martell 2008; Rahm 2004). Also, researchers have highlighted how the museum environment influences theory choice (Hooper-Greenhill and Moussouri 2000). Sociocultural theory extends Vygotsky's (1978) concept of learning as a socially-mediated process in which learners are jointly responsible for their learning. Specifically, Vygotsky outlined the idea that human activities are formed by an individual's historical development and take place in a cultural context through social interactions that are mediated by language and other cultural symbol systems. Vygotsky's theory highlights the importance of scaffolding when learning—as the temporal verbal and nonverbal guidance provided by adults when assisting children at tasks—in order to help them to move towards understanding, independent learning or task/concept mastery. The importance of guidance was evident in our review (Van Schijndel et al. 2010; Wolf and Wood 2012) and was provided in a variety of ways (modeling, posing of questions). Several researchers (DeWitt 2008; Martell 2008; Rahm 2004; Zimmerman et al. 2008) who used sociocultural theory focused their analyses on parent–child and school–group conversational interactions. For example, Zimmerman et al. (2008) examined the interweaving role of children's cognitive resources, social interaction and cultural resources in knowledge construction and meaning-making of the scientific content and practices.

In 2000, Falk and Dierking applied sociocultural theory to museum learning research to highlight not only what happens during a museum visit, but also the *where* and *with whom*. This theoretical milestone centred on the development of the contextual model of learning (CML) as a general framework for learning in museums (see also Falk and Storksdieck 2005). The CML identifies 11 factors that influence learning and sorts them into three main contexts: personal, physical and sociocultural. The personal context represents the history that an individual takes into the learning situation of a museum (i.e. individual's motivation and expectations, prior knowledge and experience, interests and beliefs, and choice and control). The physical context includes: advance organizers, orientation to the physical setting, architecture and physical space, design of the exhibit, and subsequent reinforcing events. On the other hand, the sociocultural context (i.e. within-group social mediation and facilitated mediation by others) involves visitors as part of a social group (e.g. family, school, preschool) that form a community of learners. Socially-mediated learning in museums also occurs through interactions with knowledgeable adults (parents, curators and teachers) using scaffolding strategies during programs/exhibits to maximise children's learning. Sociocultural theory (as well as a moderate use of constructivism) was also evident in Tenenbaum et al. (2004) application of Fischer's skill theory (Fischer and Bidell 1998). Here, skills are domain-specific and there is a high degree of variability across tasks and contexts (Fischer and Bidell 1998).

Overall, the specific museum environment was found to have an impact on the choice of learning theory (Hooper-Greenhill and Moussouri 2000). The theory of social practices (a type of sociocultural theory) conceptualises knowledge as practical understanding and ability, with practice being situational 'doing' in relation to social and material surroundings (Reckwitz 2002). Based on this theory, Wöhrer and Harrasser (2011) proposed a framework that helps understanding of children's practices in the context of, and in relation to the setting of, children's museum. Within this framework is a focus on children's interactions with technological objects in different settings and through games. Children's knowledge acquisition was considered to be embedded in their handling of objects and involved task performance.

Additional theories emerged from our review. For example, Milutinović and Gajić's (2010) study within the context of art museums/galleries was rich with multisensory experience activities and aligned well with Gardner's (1999) theory of multiple intelligences. Another example of theoretically-framed research within children's museums included exhibits of real-life social and nature environments (e.g. Puchner et al. 2001). Such research aligned well with Bandura's social cognitive theory (1986) given the focus on learning as a change in mental representations because of experience that could, or could not, be manifested in behaviour.

Methodological approach and information sources

The last decade of research into children's museum learning is rich with examples of how quantitative and qualitative methods can help to describe facilitating activities and strategies, children's learning experience, engagement with an exhibit, and assessing learning. For example, we found a number of the studies that used qualitative approaches to provide a more-comprehensive portrayal of children's museum learning (see "Appendix"). Compared with the previous decade, there has also been an increase in longitudinal designs about assessment of learning (e.g. Anderson et al. 2002, 2008; Rahm 2004). The findings of this review were in contrast to those of Hooper-Greenhill and Moussouri's (2000) review, for which the methodological approach was mainly positivistic and focused on hypothesis testing.

Our review revealed 31 empirical studies whose characteristics and study designs are systematically presented in the "Appendix". Much of the qualitative research performed in museums was classified as descriptive. Often case-study designs (e.g. microanalysis or multiple case studies) or action research designs were used, mainly in art museum/galleries (e.g. Martell 2008; Milutinović and Gajić 2010). Qualitative data collection included pre/post interviews, field notes and participatory observations of activities and interactions. Reviews of documents such as children's drawings were used in art museums/galleries and science centres (Martell 2008; Milutinović and Gajić 2010), whereas worksheet assignments and children's diaries were used in history and science museums (e.g. Martell 2008). The most recommended information source in all types of museums for capturing adult–child, peer–peer and child–object/exhibit interactions, learning experience, and to describe children's behaviour, were video recordings (for example, see Martell 2008).

In science and (natural) history museums, quantitative research methods typically addressed the use and effectiveness of learning activities and strategies or educational programs. Quantitative information sources used in all types of museums research often involved surveys that required children or teacher/parent to answer closed- or open-ended questions (e.g. Bamberger and Tal 2007; Murriello and Knobel 2008; Zimmerman et al. 2008). However, measuring preschool children's learning in relation to interactivity has proved to be a challenge in museum education research (Van Schijndel et al. 2010). Because a focus on children's verbalisation is best combined with is a focus on their actions, Van Schijndel et al. (2010) used an exploratory behavioural scale that measures children's behaviour and the quality of interactions.

All of the reviewed studies were of high quality, particularly with respect to clearly stating the purpose of their study, describing the study setting (e.g. type of the museum, exhibit, educational program and its duration, strategies and activities used) and specifying the people involved (e.g. museum educators, teachers, parents). As museum learning is difficult to measure (Reisman 2008), most studies we reviewed benefited from the use of the multiple instruments in assessing children's learning (e.g. Bamberger and Tal 2007; Benjamin et al. 2010; Palmquist and Crowley 2007). However, we also noted a few methodological shortcomings of the reviewed studies.

When interpreting the study results, we were cognizant of a range of limitations. First, one third of the empirical studies did not cite the number of participants. With the exception of a few studies (see "Appendix"), others specified a small sample size ($N < 100$) that influenced the power of the study. Second, most of the studies in art and children museums did not report the reliabilities associated with their instruments or coding structures. Science museums and centres, as well as history museums did, but they reported moderate to high reliabilities for the instruments used ($\alpha = 0.60$ and 0.95). Lastly, studies that primarily relied on the use of subjective measures in the assessment of learning (e.g. interviews and self-reports), could have measurement bias, which can be solved by the use of more objective measures (e.g. knowledge tests).

Overall, the challenge for researchers investigating children's learning in museums is to account for a multitude of confounding, competing and mutually-influencing factors (e.g. motivation and beliefs, design of the exhibition, social interaction; Falk and Dierking 2000). In order to answer this challenge, Reisman (2008) has argued for the use of design-based research (DBR), including both qualitative and quantitative research methodologies in a complementary way. Although this approach has been primarily used in formal education for creating complex interventions in classroom settings (e.g. Brown 1992), it is beginning to be used in science museums for examining the process of learning. Because DBR often combines qualitative and quantitative measures to study learning, it allows observing the system holistically while maintaining awareness of the changes in the learning process, interactions and resulting outcomes (Reisman 2008).

Framework of children's learning in museums

The reviewed studies focused on children's interactions with adult guides (e.g. curator, parent, teacher, scientist) and technology, accompanied with hands-on activities that facilitated children's learning. Our review revealed the dominance of facilitating strategies and activities present in seven interactivity types defined in Table 2: (1) child–adults/peers, (2) child–technology, (3) child–environment, (4) child–environment–adults/peers, (5) child–technology–adults/peers, (6) child–technology–environment and (7) total interaction. What follows is a description of interactivity according to four learning contexts: science museums, children's museums, (natural) history museums and art museums/galleries.

Science museums

Science museums and centres are valuable resources for first-hand technological exploration that often are not available for students in formal learning settings (Glick and Samarapungavan 2008). Moreover, they are considered helpful resources for supporting the inclusion of gifted children, teacher professional development and field trips (Henderson and Atencio 2007). During the last decade, the role of museum guide in science museums and centres has become more geared towards interaction with children (Cheng et al. 2011). Not surprisingly, the majority of reviewed studies (15) were within the context of science museums. Most of these studies focused on students' learning during field trips and family visits to the museum, with seven studies on preschool learning. Mainly studies of effectiveness took place within science museums and centres (see "Appendix") and they focused on the effectiveness of interactive exhibitions, museum/school interventions and coaching. Analyses performed in the reviewed studies focused on the extent of exhibit exploration, knowledge and understanding of science concepts and phenomena, and attitudes.

We also reviewed studies that demonstrated the child–environment–adults/peers interactivity type by using different levels of guidance to explore children's learning (see Bamberger and Tal 2007; Rahm 2004; Van Schijndel et al. 2010). While Van Schijndel et al. (2010) explored scaffolding, explaining and minimal coaching style on preschool children's hands-on behaviour, Bamberger and Tal (2007) inspected three levels of choice activities (free-choice, limited-choice, and no-choice interactivity). Results revealed three key findings: (1) the scaffolding coaching style implied that the guide aroused the child's investigations to the next level by asking open questions and directing the child's attention to specific exhibit parts, (2) the explaining coaching style included an exhibit demonstration and its explanation (e.g. causal connections, physical principles) and (3) the minimal coaching style (child–environment interactivity) served as the control condition (the child freely interacted with the exhibit; Van Schijndel et al. 2010).

Overall, this selection of findings revealed that different levels of scaffolding and guidance yielded differences in children's learning. That is, children showed more active manipulation with the exhibit when coached with the scaffolding style, and more exploratory behaviour when coached with the explaining style (Van Schijndel et al. 2010). While limited-choice activities yielded the most advantages (e.g. promoted teamwork during problem solving), the no-choice activities allowed students to connect experiences from the visit to their school and non-school knowledge (although strongly dependent on the guide's teaching skills). As anticipated, the free-choice activities (e.g. pressing buttons, operating objects) resulted in insufficient understanding and frustration (Bamberger and Tal 2007). Finally, in the study by Rahm (2004), the children developed an understanding about the exhibit through parents' and children's 'listening in' during ongoing conversations, observation and the manipulation of an exhibit (child–environment–adults/peers interactivity). Therefore, we consider that visits to museums that include activities founded on scaffolding, limited choice and encouraging parents–child action and conversations (that externalise children's meaning-making) are most supportive of children's learning as they develop their natural curiosity into more substantial learning.

In many science museums and centres, the rapid evolution of information and communication technologies have replaced the role of humans in facilitating children's learning (Cheng et al. 2011; Murriello and Knobel 2008; Hsu et al. 2006). As a result, multiple and overlapping interactivity types are occurring with child–technology (see Fig. 1). For example, Hsu et al. (2006) demonstrated that a child–technology–environment interaction occurred when mobile phones were employed to help to improve elementary-school children's learning in a science museum. In this study, the pre-visit learning stage included creation of a learning plan by specifying the student's subjects of interest, visit date and duration of stay. The onsite-visit learning stage took place during the student's museum visit, where he/she engaged in the learning activity using a handheld device. Learning was made personal when all the tracked learning behaviour was analysed and results informed recommendations for the student. During the post-visit learning stage, the student was encouraged to continue learning via the Internet after leaving the museum.

With advances in computer technologies and networked learning in science museums, educators and researchers have begun to create the next generation of blended learning environments that are highly interactive, learner-centred, authentic, meaningful and fun. One example of child–technology–adults/peers interactivity that involved an interactive computerised simulation exhibit (a 3D virtual brain tour combined with a video game format; Cheng et al. 2011) was found to be highly effective as a teaching and learning tool for improving the neuroscience literacy of elementary-school children. First, the exhibit involved a 3D virtual brain tour for which visitors viewed and manipulated the comparison between a normal and a methamphetamine-impaired virtual brain. Next, visitors played a driving video game that simulated driving skills under methamphetamine-abused conditions. The brain models were presented on displays (viewable by multiple people simultaneously) and children used a video game controller to navigate and manipulate the virtual brain, thereby authoring their own learning experience. While the simulation exhibit environment was effective in promoting children's understanding and attitudes, children performed better if they had parents' help (child–technology–adults/peers interaction).

Like Cheng et al. (2011), Murriello and Knobel's (2008) study employed technology in order to increase the nanoscience and nanotechnology understanding of children. During an hour-long experience guided by an actor and facilitators, visitors participated in four interactive-collaborative games and watched two narrated videos. Children recounted the rich learning experience about identifying small-scale length or the concept of tiny particles. By studying an educational multimedia experience (music, images and computer simulation) presented in an attractive, playful and modern environment, Murriello and Knobel (2008) demonstrated the combination of facilitating strategies and activities of *all* interaction types.

Children's museums

According to the Association of Children's Museums (2008) children's museums are places where children, usually under the age of 10 years, learn through play while exploring in environments designed for them. For example, one museum's slogan of "Hands on, minds on, hearts on!" (Wöhrer and Harrasser 2011, p. 473) refers to a learning concept involving physical, emotional and intellectual experiences—an often-seen characteristic of learning practices in children's museums. While our conclusions are limited to our review of six articles, the research conducted in children's museums appears to centre on defining what early learning looks like and on exploring the role of adults in children's early learning experiences.

Studies revealed that preschool children's learning within children's museums exceeds simple acquisition of facts and disciplinary content knowledge and, instead, extends into developmental areas such as procedural or cause/effect learning (e.g. Puchner et al. 2001). Although most of the six reviewed studies focused on describing the facilitation strategies and activities, two studies explored learning gains. The positive effects on children's learning emerged mainly as an outcome of active adult guidance, which provided evidence of a shifted focus from child-centred to family-centred experiences in museum learning (e.g. Benjamin et al. 2010; Freedman 2010). Museum professionals realised that, in using child-centered approaches, they had overlooked the critical role of adults as members of the learning group, and that their integration into the learning process can offer the impetus to expand the learning experience beyond the museum (Wolf and Wood 2012).

The importance of scaffolding was highlighted in most of the studies as an essential strategy for maximising children's learning during family or school visits to museums (e.g. Benjamin et al. 2010; Puchner et al. 2001; Wolf and Wood 2012). For example, Wolf and Wood (2012) present the 'Kindness tree' exhibit in the Indianapolis children's museum as an excellent example of scaffolding use. The exhibit told the story of prejudice and intolerance through the life stories of Anne Frank, Ruby Bridges and Ryan White while encouraging children to have the power to confront intolerance by using their words, actions and voices. Scaffolding occurred when parents read messages about kindness acts from magnetic 'leaves' and related those experiences to the child as he/she completed the activity. Scaffolding was more frequent and intensive at exhibits that included activities with clear directions for adults, that were attractive for them (but children had trouble performing correctly on their own) or that invited participation through scripts/labels of the exhibits (Puchner et al. 2001). In line with this, Wolf and Wood (2012) recommended that that content of an exhibition can be scrutinised for potential scaffolding opportunities by determining various levels of content accessibility or providing a learning framework for specific age groups.

Also derived from sociocultural theory is the acknowledgement of collaborative verbal parent–child engagement as a potentially powerful mediator of cognitive change. Therefore, it is no surprise that parent–child conversational interactions were highlighted in research on children's museums research. Benjamin et al. (2010) elaborated on the effectiveness of open-ended 'wh' questions (e.g. *What? Why?*) during a child–adults/peers interaction in a museum. Ideally, these questions can reflect and change what is understood by focusing children's attention on what is available to learn, obstacles and problem-solving strategies. In Benjamin's study, the conversational instruction coupled with hands-on activities (child–environment–adults/peers), resulted in children's abilities to report program-related content immediately after the exhibit and again after two weeks.

Guided (either by parent or museum educator) hands-on activities were the leading effective activities for facilitating children's learning in most children's museums and a representation of child–environment–adults/peers interactivity. For example, an intervention study (Freedman 2010) revealed a significant positive change in children's knowledge about healthy ingredients after a 'Healthy pizza kitchen' program (a presentation followed with a hands-on mock pizzeria exhibit). In this study, Freedman conducted a playful experiments strategy (child–environment and child–environment–adults/peers interactivity) which presented an example of how hands-on activities help to facilitate children's learning through child–adults/peer and child–environment interaction.

Overall, strategies and activities applied in children's museums represent the interactivity types child–adults/peers and child–environment, as well as predominantly their overlapping area (child–environment–adults/peers). Despite the positive influence of parental involvement on children's learning found in children's museums, Wolf and Wood (2012) indicated that parents' beliefs and roles about guiding their children's learning are often divergent from ideas highlighted by museum professionals and researchers. For example, a lack of understanding of the importance of play for children's learning, and parents discomfort or hesitation to play in public, lead them to simply watch instead of interact while their children play.

(Natural) history museums

Our review included 11 studies set in historical museums (generally natural museums). Most studies we reviewed described museum learning as meaning-making during a field trip or family visit to a museum, with effectiveness being the focus of examination in five studies (Melber 2003; Sung et al. 2010; Tenenbaum et al. 2010; Wickens 2012; Wilde and Urhahne 2008). History and archeological museums feature a plethora of information, normally in the form of science specimens and cultural or historical artifacts (Cox-Petersen et al. 2003). Historical museums with three-dimensional models or live exhibits can afford children the opportunity to construct richer and more-realistic mental representations relative to traditional digital and pictorial illustrations in textbooks. Furthermore, with access to various historical documents, images and collection items (often unavailable in formal settings as schools), children are not just exposed to primary resources as learning tools, but also to interpretations of the past that guide them through history (Wolberg and Goff 2012).

History museums are ideal places for stories to be told and, because storytelling serves as a fundamental way of learning and defining human values and beliefs, interactivity can help to "make connections between museum artifacts and images and visitors' lives and memories" (Bedford 2001, p. 30). Dramatic narratives or storytelling were highlighted in all reviewed (natural) history museum papers as having a pivotal role in facilitating children's learning (e.g. Bowers 2012; Hall and Bannon 2006; Kelly 2007; Tenenbaum et al. 2010). By including a role for a knowledgeable adult (or a technological aid) to tell stories, these studies provided examples of two interactivity types (child–adults/peers and child–technology) and the overlapping framework areas (child–environment–adults/peers interactivity and total interactivity).

Wickens (2012) also described the use of a storytelling activity for preschool children as part of a three-mode structure (story/tour/activity). The three-mode structure strategy was identified in our framework as belonging to the overlapping area of child–environment–adults/peers (see Fig. 1) because it combined narratives, hands-on activities, free play, free exploration and guided multisensory experience. Children participated in the interactive story, then moved to the gallery to explore the themes, and returned for the creative activity. Results confirmed that the three-mode structure helped children to feel a sense of comfort because their familiarity with story time and art-making activities helped them to have control during their learning and facilitated learning. Moreover, Hall and Bannon (2006) found that narratives provided by a computer within an exhibit can also engage children by affording an overall coherence and intelligibility to their museum activities. In their study, exhibit interactivity was examined in two rooms: the study room where children heard stories if they pressed 'the virtual touch machine' and the 'room of opinions' where children were encouraged to explore clues and develop their own opinions about artifacts through hands-on activities. This particular study design provides an example of the total interactivity type represented through our framework (i.e. the combination of activities from all three main interactivity types, namely, child–adults/peers, child–technology and child–environment).

Inquiry-based activities and conversations at the exhibit or as part of problem-solving with a mobile guide system (MGS) can be positioned in the overlapping areas of our framework (child–environment–adults/peers, child–technology–environment and total interactivity) and were commonly described and highlighted as successful for helping children to gain knowledge and meaning about the past (e.g. studies by Melber 2003; Sung et al. 2010). For example, the MGS problem-solving strategy designed by Sung et al. (2010) involved total interactivity. In contrast to the commonly-used audio-visual guiding system that provides only information about each exhibit (via pictures, texts, voice narratives), the MGS offered a problem-solving scenario that guided the learners to look at the exhibits, browse the information on their mobile phone, discuss it with their peers, and solve a series of questions to complete the quests. Because results revealed increased interest and enjoyment during the activity, recommendations include that museum educators and teachers utilise MGS, and that researchers and system developers design more guided-learning activities and systems that constitute problem-solving tasks with inquiries. Limitations include learners being absorbed by amazement about the technological possibilities, the 'magic' of the concealed technology (Hall and Bannon 2006), rather than on the task-at-hand. Future research could involve how technology can be made less obvious and how concealing technology might influence children's learning experience (Hall and Bannon 2006; Sung et al. 2010).

Inquiry was also part of the learning strategy 'thinking routines' (child–adults/peers interactivity type)—identified by Wolberg and Goff (2012) as advantageous in supporting young children's learning in museums. With this strategy, children were encouraged to see, think and wonder when encountering a new object or image. An important goal of this strategy was to expose students to the language of thinking through guided conversation and questions (posed by both museum educator and children) in order to deepen understanding and gain knowledge. The information gathered by a student did not come just from visual cues within the collections, but also from thoughtful inference, reason and deduction—a strategy that could further enhance children's learning even within the limited period of a museum visit. By using careful observations and thoughtful interpretations involving an image or artifact, students' thinking and learning became more visible to themselves, teachers and peers.

Wilde and Urhahne (2008) found open-ended tasks involving child–adults/peers interactivity to be less successful than closed tasks (or a combination of both) in contributing to knowledge gains and, in particular, less intrinsically motivating for fifth-grade students. The children showed more interest/enjoyment with closed tasks and greater short-term and long-term retention of knowledge (after four weeks) through closed and mixed tasks. On the other hand, children who engaged with open-ended tasks did not show evidence of increased learning and showed less task-related intrinsic motivation. As a result, Wilde and Urhahne recommend a museum visit with more structured tasks and a certain amount of instruction (i.e. closed tasks) for children. Tenenbaum et al. (2010) emphasised the importance of activities within interactivity types child–environment and child–environment–adults/peers by suggesting that hands-on support for children (e.g. booklets, backpacks with props) through exhibits can enrich their conversations as they require more engagement with the museum exhibit. Overall, Melber (2003) recommends a combination of hands-on and inquiry-based activities as effective (particularly for gifted elementary school-aged children) at influencing attitudes and understanding of the scientific work. For example, Melber found that children were fascinated by the opportunity to handle objects and to have the time to critically look at and discuss the object's characteristics with peers and/or curators. In addition, children became aware of the different scientific careers associated with a museum in an engaging and personally-relevant manner.

Palmquist and Crowley (2007) stressed that parents of gifted or 'expert' children should be particularly cautious when facilitating their learning. Through family conversation analysis with children (ages 5 and 7 years), Palmquist and Crowley found that, when compared with children of less experience and content knowledge, children developing an "island of expertise" (p. 784) had parents who provided a reduction in active contributions to learning conversations. In fact, children with less experience focused on the features of objects and learned together through conversations with parents. Here we recognise a knowledge gap about how to support and extend learning trajectories in museums and, in particular, how to use the expert knowledge of children as a platform for future learning.

Art museums/galleries

Art museums/galleries are often seen as imposing places that keep a myriad of valuable artworks and objects and that are intolerant for any kind of child-centred exploration (Weier 2004). With "ever-present security guards, overwhelming architecture, stillness, quietness, and artworks displayed at adult height" (Weier 2004, p. 106), latent messages project that children are not welcome. Art museums are unfortunately the most reluctant type of museum to embrace early childhood visitors (Mallos 2012) despite how children are naturally attracted to contemporary art—to its abstractions, diversity, scale and experimentation, and by being open-minded and spontaneous in their interpretations. According to Jeffers (1999), when welcomed and empowered by developmentally-appropriate learning strategies and activities, children can "actively connect" (Jeffers 1999, p. 50) with the museum and its contents, providing imaginative insights and new perspectives about the artworks.

Of nine reviewed studies, there was only one study of effectiveness (Burchenal and Grohe 2007) that assessed the effects of the program on the development of critical thinking skills. Most of the reviewed studies and descriptions of children's learning in art museums took place in Australia and the UK and were based on the partnership between museum educators, researchers and artists. The museum programs/workshops mainly aimed to facilitate the development of young people's critical-thinking skills (e.g. Burchenal and Grohe 2007; Luke et al. 2007). The dominant activity in facilitating children's learning in art museums/galleries was hands-on activity (see Burchenal and Grohe 2007; Krakowski 2012; Mallos 2012; Milutinović and Gajić 2010). As stated by Mallos (2012), hands-on activities in art museums/galleries encourage children to make connections to ideas or materials with which the artists worked and, by relying on a child's experience, deepen his/her understanding about the artwork.

In order to understand the work of art and to freely express themselves, children engaged in diverse hands-on activities in the reviewed studies. The program designers often utilised hands-on activities as part of a strategy that can be positioned in the overlapping child–environment–adults/peers area of our framework. For example, Mallos (2012) described strategies useful for cultivating children's encounters with art which are very similar to the three-mode strategy 'Listen, Look & Do' applied in history museums. Mallos used a 'three-window approach' which consisted of: the experiential window, or hands-on approach—inviting children to touch, manipulate or respond using bodily movements; the narrative window—allowing children to experience an object through the medium of story; and the aesthetic window—focusing on having children describe the visual and aesthetic qualities of the object encountered.

In two reviewed studies, the artist (along with the museum educators and parents) played an essential role in facilitating children's learning. For example, Mallos (2012) describes how gallery members collaborated with more than 100 local and international contemporary artists to develop and take part in various exhibitions, installations and workshops for families. Weier (2004) however, suggests that, by allowing children to take the lead (i.e. act as a tour guide for parents or peers), art museums can provide opportunities for self-expression, choice and control during visits. Weier (2004), also noted that, by allowing young children the opportunity to be tour guides, they can access art on their own level and terms, in contrast to learning an expected set of meanings or accepting another's interpretation of an artwork as the only possibility. Once children experience a sense of accessibility, enjoyment and motivation when viewing and discussing artworks on their own terms, they are more likely to be ready to have their conversations extended to include visual arts concepts.

By emphasising the role of the adults and peers in guiding children's learning and their interactions, Weier (2004) represented the child–adults/peers interactivity area of our framework. The advantage of allowing children to take the lead in museum learning was also supported by the research of Falk and Dierking (2000) who found that children are more motivated when having choice and control over their museum encounters. Weier (2004) also underlined the importance of having a supportive and responsive adult (i.e. curator, artist, parent) during child-led tours build on children's conversations and introduce the language and concepts of the visual arts or the materials used. The information about the artwork should only be used as a trigger for discovery, which assists children to form hypotheses, create stories, build meanings and make connections based on personal experiences and feelings about the work.

Suggestions about introducing visual arts language and concepts at appropriate junctures in the child's dialogue, using a range of "scaffolding behaviors" (Weier 2000, p. 1999), include:

- focusing children's attention on a particular aspect of the artwork
- asking open-ended questions
- providing explanations
- recalling facts or experiences to encourage associations
- making suggestions; initiating a line of thinking that children can follow
- hypothesising (or imagining or wondering) to spark curiosity and encourage further exploration, and
- prompting with cues to support divergent thinking; and posing problems (Weier 2000, 2004).

Burchenal and Grohe (2007) provide one example of prompting through the study of Visual Thinking Strategies (VTS)—a beneficial approach for use in both the classroom and museum settings when seeking to promote the development of critical-thinking skills. By concentrating on conversational interactions between a museum educator and children (child–adults/peers interactivity), VTS starts with questions as prompts for children, encouraging them to provide evidence for their ideas. By carefully observing and discussing works of art, students had the opportunity to apply previous experiences and knowledge to make meaning of artwork on their own terms.

A possible model for the successful integration of multisensory enriched activities in museums is presented by Milutinović and Gajić (2010) through the six-month educational program 'Feel the art' in the Gallery of Matica srpska in Serbia. (The first author of this paper contributed to this program.) With the goal of encouraging children to employ all senses when confronted with artwork, this museum program provides an example of the child–environment–adults/peers type of interactivity identified in our framework. For example, children recognised what, from the paintings, could produce sounds (e.g. sea waves, an erupting volcano, birds, frogs, rustling leaves) and imitated the sounds with musical instruments. Results revealed children's descriptions of paintings or objects that reflected interest development and the capability to participate in multisensory art activities.

In order to understand artwork, Mallos (2012) recommends that children are incorporated into the artwork. For example, Japanese artist Yayoi Kusama's (as cited in Mallos 2012) encouraged children to freely 'obliterate' a bare environment by sticking dots everywhere. In this way, children could take part in the art-making experience and see themselves through the screen of dots that was the subject of artist's work. Mallos (2012) also described an activity in which children were asked to design and construct a bridge with fine pieces of cane and masking tape using artists' line drawings of various bridges. By this immediate interaction with the museum environment, these activities present an example of the child–environment interactivity.

The imaginative aspect of play is one of the most powerful learning tools that children can use in order to make sense of their world (Vygotsky 1967). Guided and facilitated play (child–environment–adults/peers interactivity) was a motivating strategy for multisensory and stimulating learning in art museums. For example, Krakowski (2012) found guided play through dressing-up and role-playing activities that allowed children to discover 'who they could be, who they might be, who they want to be', with the aim of reflecting and understanding different perspectives. According to Krakowski, guided play embodies many of the characteristics of spontaneous or free play, but it is teacher-directed and is used intentionally for educational purposes. In particular, it "engages children in pleasurable and seemingly spontaneous activities that encourage exploration and learning" (Hirsh-Pasek et al. 2008, p. 27).

Discussion

The last decade of research into children's museum learning has provided rich descriptions of children's learning in various types of museums worldwide. In our review, we focused on the activities and strategies that mediate informal learning. In contrast to the review by Hooper-Greenhill and Moussouri (2000), in which research in children's museum learning was dominated by studies from science museums and centres in the US, much of the research we reviewed was conducted in Australia, China and the UK. Our review also revealed increasing evidence from museum research in European countries such as The Netherlands, Germany, Austria, Italy and Serbia. Science museums and centres remained a major focus in the literature, with research in natural history museums, children's museums and art galleries increasing over the decade. Like Hooper-Greenhill and Moussouri (2000), we believe that additional research could have been conducted, but not yet published.

The shift in the literature towards the importance of interaction in children's museum learning, notable by its presence in all museum types (see "Appendix"), contributed to the development of a framework of facilitating strategies and activities in children's learning in museums. Three main types of interactivity, by which children's learning was facilitated, were identified: *child–adults/peers*; *child–technology*; and *child–environment*. However, all facilitating strategies and activities made use of one or more of the interactivity types, which led to categorising some articles as representative of overlapping interactivity types (see Fig. 1 for the illustration of our framework). The most-common activities in all museum types were hands-on activities, which could include individual and self-controlled engagement (child–environment interactivity), as well as guidance from a knowledgeable adult/peer (child–adults/peers interactivity) or a computer (child–technology interactivity).

Which learning theories informed the research on museum learning?

In response to our first research question (*Which learning theories informed the research?*), we found more research that was framed by sociocultural theory (and less by socio-constructivist theory) and related theories on museum learning (e.g. the contextual model of learning). These theories underline the social nature of museum learning and the importance of children's interaction with adults/peers and technology. While the previous research framework and program designs focused on the learner's individual role in knowledge construction and meaning-making, an awareness of interactivity as an indispensable characteristic of children's museum learning (child–adults/peers interactivity, child–technology interactivity) now reflects the theoretical influence of socio-constructivism and sociocultural theory. Moreover, while previous museum learning research has centred mainly on children visiting exhibits (Hooper-Greenhill and Moussouri 2000), recent articles on all museums types tend to describe children's learning through participation in programs or workshops, or through the use of educational materials and objects.

Which methodological approaches were applied in the reviewed studies?

The wish to do justice to the social complexity of museum learning was also reflected in the methodological approaches applied (and addressed our second research question). An awareness of the benefits of not only quantitative, but also qualitative, methodological approaches in museum learning research is apparent (see "Appendix"). Descriptions of learning strategies, activities and experiences of participants were provided and actual learning outcomes were assessed. Our review revealed an increased number of longitudinal studies, thereby helping to fill a research gap identified in a previous review (Hooper-Greenhill and Moussouri 2000), and reflecting an increased awareness of 'time' in children's museum learning: museum learning takes time, because knowledge is being accumulated over time (Rahm 2004).

Who and what facilitates museum learning: which activities and strategies are being used?

In science museums and centres, the most prominent learning strategies and activities were positioned at the heart of our framework (Fig. 1): a combination of three main interactivity types (child–environment–adults/peers, child–technology–adults/peers and child–technology–environment interactivity type). The dominant activities were interactive exhibits with technology, guided and free-choice or limited-choice hands-on activities. Here, the impact of technology and teaching guidance was most prominent, especially through the designs and applications of the mobile guiding systems and interactive games. Children interacted with the technology, which invited them to engage (individually or with the guidance of knowledgeable adults) in other activities (such as hands-on activities) in the museum environment. Although the use of technology in facilitating children's learning extends to other museum types (e.g. history and art museums/galleries), the strategies and activities used in children's and art museums/galleries were identified as child–adults/peer interactivity (e.g. scaffolding, children as guides, storytelling activities), child–environment interactivity (e.g. hands-on activities, free exploration) and as a combination of both (e.g. playful experiments, the three-window approach, multisensory experiences).

While research on children's museum learning clearly demonstrated a shift from child-centred to family-centred, the scaffolding strategy dominated in our review. In contrast, activities and strategies used in history museums, as in science museums, spanned most interaction types and their combinations (e.g. open tasks on the worksheets, booklets and backpack with hands-on activities, free exploration), with an emphasis on narratives (e.g. storytelling activity guided either by the adult or by a computer).

What knowledge has the research about children's learning in museums yielded?

We found that research on children's museum learning during the last decade provides knowledge about learning experiences, as well as an appreciation of the effects related to several facilitating strategies and activities in children's learning. In general, we found growing evidence suggesting that museum exhibitions, when supported with facilitating strategies and activities, can positively influence children's science attitudes and concept knowledge, understanding, teamwork, communication and group communication skills, and critical thinking skills in history, science, arts and humanities. Although we noted some differences in children's learning between the museum types based on the strategies and activities that facilitate their learning, we also found many similarities. Our review revealed activities and strategies that evoked curiosity, excitement, memorable moments, discussions and explorations during exhibits, together with peers or/and family members form a common base for children's learning in all museum types. Based on these findings, we recommend hands-on activities, narratives and play, and an emphasis on the importance of scaffolding by a knowledgeable adult/peer or support through technology.

Future research

Much remains unknown about actual learning and museum learning outcomes. Future research could involve designing and testing the effectiveness of the facilitating strategies and activities noted in our framework. In particular, we recommend future research on museum–school learning as well as the effects of family learning in art museums/galleries and children's museums that extends beyond the case study approach. Museum educators will also benefit from the development and validation of reliable measurement instruments. Several recommendations for future research on children's learning in museums can be formulated, beginning with more design-based research (DBR).

Design-based research

Although DBR has been previously used in science museums, we believe that it could offer a significant contribution for all museum types. Interventionist in nature, and by combining qualitative and quantitative research methods, this approach could test the effects of various learning strategies and activities (described in our interactivity framework) on children's learning gains. Also, DBR could help to facilitate the design and testing of new strategies and activities and confront the range of theoretical perspectives. Specifically, through the process of design, museum educators and researchers could collaborate together and apply key facilitating strategies and activities (typical for one museum type) across museum types to explore their effects on children's learning and the process of learning within different museum environments. For example, with a DBR approach, researchers could ask: How can the level of interaction types be increased and boost the effects of learning strategies and activities in different learning settings? The research procedure for answering this question could involve designing an intervention based on the offered framework and theoretical approaches and with naturalistic observations.

Video-based methodologies

Video recordings such as those used in the video-based interpretative case study approach or with the quantitative exploratory behaviour scale, can offer deeper insight into both the quantity and quality of children's interactions during learning. Besides being applied in science museums, video recordings could be used in other museum types as well. Also, these tools can be a valuable source for museum educators in understanding their own actions as facilitators (Martell 2008; Van Schijndel et al. 2010). Video recordings could be supplemented with the child's personal perspective in the video recording process. That is, the child's learning experience about a museum exhibit or a program could be recorded by his/her head-mounted camera (e.g. mobile eye-tracking apparatus) and provide detailed engagement data about a child's attention and interaction with museum educators and objects.

Co-creating during the research process

In addition, we suggest more attention to children's perspective in the research process (i.e. to include them, not only as research subjects, but as co-creators of the process and outcomes). We suggest involving children in focus groups to gain a more realistic picture about agendas, interests, values and beliefs, in contrast to those interpreted by adults (as is the case in most studies that we reviewed). Also, by including their voices throughout the research process, children could contribute their ideas and describe their interests, thereby informing the design of current and future programs, activities and exhibitions. This could help with the challenge of documenting the effectiveness of a specific learning strategy and activity in a specific museum type.

Future studies on children's museum learning should include a wider framework of learning factors both in and out of museums, because much of the research reviewed still focused on the individual family group/child conversations and their immediate experience within the museum. Overall, the implication for museum learning practice is to strengthen a partnership of institutions as part of a wide sociocultural context (e.g. schools, preschools, families, cultural institutions) and the museum environment, and combine their advantages in order to promote children's optimal learning. A beneficial partnership could involve co-developing curriculum-based materials supplementary to preschool/school use, which focus on exhibit contents in museums. As a result, a bond between practitioners (e.g. school teachers, scientists and artists) could be strengthened through the process of working together to design and conduct museum educational programs. Our framework supports the idea that museum educators and teachers could partner and supply practical tools for designing effective learning experiences as part of the children's regular museum visit or a school field trip.

Overall, the field requires more qualitative and quantitative evidence to further understand the extent to which the strategies and activities from our framework are effective for children's learning, as well as which of these strategies, if any, are most effective in certain situations. Although we presented some studies with innovative mobile and computer technologies deployed in museums, there is still a dearth of research concerned with how this new generation of learning systems in museums can be developed to enhance children's museum learning. Given the different learning strategies and activities presented in our framework, the next step is to explore what competencies of museum educators are needed when applying these strategies and activities. Based on this knowledge, the professional programs for museum educators could be developed and strengthened, with a focus on pedagogy directed at successful museum learning processes.

Limitations

While the current review provides the first overview of studies on children's learning in museums beyond the US, it is not without limitations. First, although we reviewed 44 studies on children's learning across various museum types, the latest study included in our review was conducted in 2012. Results from reviews are most useful when representing the current state of research, but we were unable to find consensus on the timing of updates (Yoshii et al. 2009). Second, in our review, we used the Web of Science database because of its capability to search across disciplines and we reviewed relevant journals on museum topics. However, the search strategy could have been expanded by using additional databases and additional search terms. Despite these limitations, we think that our review approach and subsequent framework have contributed a valuable overview and description of the field for future researchers.

Conclusion

We highlighted the need for museums to transform themselves from "being about something to being for somebody" (Weil 1999, p. 229) and, in this case, children. As detailed through our review, this need implies that museum researchers and educators should co-create learning environments that welcome children with effective and powerful learning strategies and activities that enhance their learning by combining different interactivity types. Our developed framework of facilitating strategies and activities for children's museum learning offers a valuable knowledge base for museum educators and researchers, as well as teachers and families when visiting museums. Specifically, by distinguishing interaction types that are used in different museum learning environments, this framework offers a practical map on how to design and research the educational programs/exhibitions. This review of research on children's museum learning provides guidance for next steps that move towards a greater focus on interactivity, in its varied forms, with attention to the merit of scaffolding. Ultimately, research that continues in this direction is likely to contribute greatly as we seek to support learners in informal settings.

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Appendix

See Table 3.

Table 3 Overview and characteristics of the empirical studies

References	Type of museum	Strategies/ activities	Findings	Methodological characteristics
				Study design *N* = (number of participants) Data (i.e. how is learning, engagement and/or experience measured) * = Effectiveness study and its explanation
Anderson et al. (2008)	A + C + D	1a, 1b, 1c 3a, 3b, 3c, 3d 4a, 4b, 4c	Children's agendas had the potential to profoundly affect their museum experience and learning	Longitudinal *N* = unknown Field notes and observations, conversation analysis
Anderson et al. (2002)	A + C + D	1a, 1b, 1c 3a, 3b, 3c, 3d 4a, 4b, 4c	Exhibits and programmatic experiences embedded in the familiar sociocultural context of the child's world (e.g. story play) were more powerful mediators of memory, enjoyment and learning than those decontextualised	Longitudinal *N* = 99 preschool children Interviews
Ash (2003)	A	1a, 1b, 1c	Biological principles supported reasoning across contexts, and were particularly useful for children who don't yet have sophisticated domain knowledge	Case study, longitudinal *N* = unknown Interviews, family conversations
Bamberger and Tal (2007)*	A + C+	4b, 3c	The limited-choice activities offered scaffolding, controlled learning, enhanced deeper engagement, and linkage to the prior knowledge, science curriculum and life and experience	Descriptive *N* = 750 students Observations, interviews, worksheets The effectiveness of limited-choice activities on scaffolding and deeper understanding
Benjamin et al. (2010)*	B	1a, 1b, 1c 4b, 4d	Caregivers provided with conversation instruction asked more "wh" questions, made more associations, and engaged in caregiver-child joint talk. After 2 weeks, the children in the building and conversation group instruction were the best in identifying pictures with the strongest structures	Experiment *N* = 121 children Questionnaires, paired-comparison picture task, analysis of conversations in a museum, and delayed memory conversations at home Effectiveness of caregiver instruction prior to exhibit on caregiver-child interactions and children's learning

Table 3 continued

References	Type of museum	Strategies/ activities	Findings	Methodological characteristics
Burchenal and Grohe (2007)*	D	1a, 1b 3a, 3b, 3c 4b	The art-viewing program using the VTS approach in both classroom and museum promoted the development of critical-thinking skills	Quasi-experiment $N =$ unknown Observations, conversation analysis The program led to more instances of critical thinking skills
Cheng et al. (2011)*	A	2 5	Children showed understanding and attitudes towards the impact of methamphetamine abuse on the brain; parents' help increased the level of performance	Pre-post experiments $N = 175$ students Survey questionnaires Effectiveness of the interactive exhibition on children's level of drug understanding and attitudes
Cox-Petersen et al. (2003)	C	1a, 1b, 1c	School tours were organised in a didactical conflicting way to science education reform documents and research. The students showed high satisfaction with the tour, but low levels of science learning	Descriptive $N = 30$ teachers, $N = 85$ children Observations, interviews
DeWitt (2008)	A	1a, 1b 4b	Students utilised their existing science understandings to interpret and explain their interactions with exhibit	Descriptive $N = 123$ students Interviews prompted by video clips and still photos
Freedman (2010)*	B	1a 4b	Students were able to identify healthy and unhealthy ingredients (e.g. low-fat cheese, mushrooms, sausage, high fat cheese)	Intervention $N = 151$ Questionnaires The effectiveness of a field trip intervention Healthy Pizza Kitchen on teaching basic nutrition concepts and creating balanced meals
Glick and Samarapungavan (2008)*	A	1c 3c, 3d	Participation in the research-designed field trip-related classroom activities before and after the field trip enhanced students' learning about wolves	Quasi-experiment $N = 30$ children Interviews Effectiveness of the intervention on students' science learning from a school field trip
Hall and Bannon (2006)	C	7	The study room and the room of opinions encouraged children to explore clues and information related to objects, and develop their own opinions about artifacts	Design and evaluative $N = 362$ children Participant observations

Table 3 continued

References	Type of museum	Strategies/ activities	Findings	Methodological characteristics
Hsu et al. (2006)	A	2 6	Demonstrated feasibility of the knowledge-based mobile learning framework for museums	Descriptive $N =$ unknown Unknown
Krakowski (2012)	D	1a, 1b 4a, 4b	The guided play was seen as a valuable vehicle for engaging young children in museum	Self-study $N =$ unknown Observations
Luke et al. (2007)	D	1a, 1b 3a 4b	The implemented measure for assessing critical-thinking skills was seen as a valuable diagnostic and training tool for practitioners in enhancing children's critical thinking skills	Instrument construction $N =$ unknown Interviews, conversational analysis
Mallos (2012)	D	1a, 1b 3a, 3b, 3c, 3d, 4a, 4b, 4c	The collaboration between artists and museums created for children memorable encounters with contemporary art	Action study $N =$ unknown Observations
Martell (2008)	A + D	1b 3a, 3d 4b	Field trip-based learning looked for the most part like learning in schools in terms of the use of specific cultural tools as initiation-response-evaluation (IRE) and textbook. Students were provided with syntactic knowledge about art, and substantive knowledge about science	Case study $N =$ unknown Journals, assignments, interviews, conversation analysis
Melber (2003)*	C	1a, 1b, 1c 3a, 3c 4b	Greater understanding of science careers, desire to explore science careers, increased content knowledge and understanding	Quasi-experiment $N = 31$ Questionnaires for children and parents The effectiveness of inquiry-based activities on attitudes toward science careers, understanding of scientific work and scientists, and content knowledge gains
Milutinović and Gajić (2010)	D	1a, 1b, 1c, 3c 3d 4a, 4b, 4c	Children gave rich descriptions about the objects, showed high motivation and the capability to take part when discussing them and the artworks	Action research $N = 170$ children Observations, worksheets, conversational analysis, analysis of drawings

Table 3 continued

References	Type of museum	Strategies/ activities	Findings	Methodological characteristics
Murriello and Knobel (2008)	A	7	Children expressed a rich learning experience about identifying small scale length or the concept of tiny particles	Evaluation $N = 814$ children; $N = 338$ general public; $N = 23$ school visitors Questionnaires and interviews Effectiveness of interactive exhibit NanoAventura on approaching and understanding nanoscience
Palmquist and Crowley (2007)	C	1a, 1b, 1c	Parents with novice children more actively engaged them in learning conversations than parents with expert children	Descriptive and correlational $N = 42$ families Interviews, questionnaires, conversation analyses
Puchner et al. (2001)	B	1b 3a, 3b, 3c 4a, 4b, 4c, 4d	Simple cause-and-effect learning during exhibits was more likely to occur with adult interaction than without	Descriptive and correlational $N = 101$ Observations and conversation analysis
Rahm (2004)	A	2 3c 4b	Supported that museums are one of the resources for science literacy development	Case study, ethnography $N =$ unknown Observations, field notes, conversational analysis
Sung et al. (2010)*	C	1c 6 7	Problem-solving mobile strategy increased the child–adult/peer interactions, learning discussions and attention during exhibit	Experiment $N = 65$ children Observations, questionnaires No learning effects of electronic guidebooks
Tenenbaum et al. (2004)*	A	1c	Children developed new science concepts, such as buoyancy, bubbles and currents	Intervention $N = 48$ children Questionnaires, tasks Effectiveness of the combined museum/ school intervention on the children's content knowledge and concept complexity about water
Tenenbaum et al. (2010)*	C	1a, 1b, 1c 3c, 3d 4b	Children engaged in more historical talk, and spent more time with the exhibit when they used booklets and activities	Quasi-experiment $N = 58$ families Observations, conversation analysis

Table 3 continued

References	Type of museum	Strategies/activities	Findings	Methodological characteristics
Van Schijndel et al. (2010)*	A	1b 3a, 3b, 3c 4b, 4d	The scaffolding style yielded more active manipulation, while the explaining style more exploratory behavior	Experiments $N = 71$ Exploratory behavior observations Effectiveness of the scaffolding, explaining and minimal coaching style on children's hands-on behaviour during exhibit
Wickens (2012)*	C	1a 3a, 3b, 3c 4c	Listen, Look & Do structure helped children to feel a sense of comfort, controlled their learning and improved knowledge about Duke E's life, music and lifestyle in the period he lived in	Longitudinal case study $N =$ unknown Interviews with teachers, children The effectiveness of the Listen, Look & Do on children knowledge about Duke E's life and music
Wilde and Urhahne (2008)*	C	1a, 1c	Open tasks were less successful and intrinsically motivating in contrast to closed and mixed tasks	Experiment $N = 207$ children Questionnaires The effectiveness of closed tasks on gaining knowledge and intrinsic motivation
Wöhrer and Harrasser (2011)	B	3a, 3b, 3c 4a, 4b, 4c	Children experimented and played with scientific technologies. They showed gendered-related differences in the object usage	Ethnographic $N = 220$ children Participant observations, conversation analysis
Zimmerman et al. (2008)	A	1b, 1c	Children and parents contributed to the conversation about biology. They had different intellectual roles during the conversation (e.g. skeptic, expert)	Case studies $N = 44$ (15 families) Family conversation analysis

A = science museum and centre, B = children museum, C = (natural) history museum, D = art museum/gallery. 1a = narratives, 1b = explanations, 1c = inquiry-based activities, 2 = interactive exhibit by mobile/computer, 3a = hands-on activities, 3b = free play, 3c = free exploration, 3d = worksheets, booklets, 4a = guided play by adult/peer, 4b = guided hands-on by adult/peer, 4c = guided multisensory experience by adult/peer, 4d = scaffolding, 5 = technology interactive exhibit guided by adult/peer, 6 = mobile guiding system with activities from museum environment, 7 = mixture of all

References

*References marked with an asterisk are those on which this article's review was based.

American Alliance of Museums 'Museum Financial Information Survey' (2009). http://www.aam-us.org. Accessed June 23, 2015.

*Anderson, D., Piscitelli, B., & Everett, M. (2008). Competing agendas: Young children's museum field trips. *Curator: The Museum Journal, 51*(3), 253–273. doi:10.1111/j.2151-6952.2008.tb00311.x.

*Anderson, D., Piscitelli, B., Weier, K., Everett, M., & Tayler, C. (2002). Children's museum experiences: Identifying powerful mediators of learning. *Curator: The Museum Journal, 45*(3), 213–231. doi:10.1111/j.2151-6952.2002.tb00057.x.

*Ash, D. (2003). Dialogic inquiry and biological themes and principles: Implications for exhibit design. *The Journal of Museum Education, 28*(2), 8–13. http://www.jstor.org/stable/40479283.

Association of Children's Museums. (2008). http://www.childrensmuseums.org/about/faq.htm. Accessed May 23, 2012.

*Bamberger, Y., & Tal, T. (2007). Learning in a personal context: Levels of choice in a free choice learning environment in science and natural history museums. *Science Education, 91*(1), 75–95. doi:10.1002/sce.20174.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice-Hall.

*Bedford, L. (2001). Storytelling: The real work of museums. *Curator: The Museum Journal, 44*(1), 27–34. doi:10.1111/j.2151-6952.2001.tb00027.x.

*Benjamin, N., Haden, C. A., & Wilkerson, E. (2010). Enhancing building, conversation, and learning through caregiver-child interactions in a children's museum. *Developmental Psychology, 46*(2), 502–515. doi:10.1037/a0017822.

*Bowers, B. (2012). A look at early childhood programming in museums. *Journal of Museum Education, 37*(1), 39–48.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences, 2*(2), 141–178. doi:10.1207/s15327809jls0202_2.

*Burchenal, M., & Grohe, M. (2007). Thinking through art: Transforming museum curriculum. *Journal of Museum Education, 32*(2), 111–122. http://www.jstor.org/stable/40479582.

*Cheng, M., Annetta, L., Folta, E., & Holmes, S. Y. (2011). Drugs and the brain: Learning the impact of methamphetamine abuse on the brain through a virtual brain exhibit in the museum. *International Journal of Science Education, 33*(2), 299–319. doi:10.1080/09500693.2010.482571.

*Cox-Petersen, A. M., Marsh, D. D., Kisiel, J., & Melber, L. M. (2003). Investigation of guided school tours, student learning, and science reform recommendations at a museum of natural history. *Journal of Research in Science Teaching, 40*(2), 200–218. doi:10.1002/tea.10072.

*DeWitt, J. E. (2008). What is this exhibit showing you? Insights from stimulated recall interviews with primary school children. *The Journal of Museum Education, 33*(2), 165–173. http://www.jstor.org/stable/40479641.

*Falk, J. H. (2004). The director's cut: Toward an improved understanding of learning from museums. *Science Education, 88*(4), S83–S96. doi:10.1002/sce.20014.

*Falk, J. H., & Dierking, L. D. (2000). *Learning from museums: Visitor experiences and the making of meaning*. Walnut Creek, CA: AltaMira Press.

*Falk, J. H., & Storksdieck, M. (2005). Learning science from museums. *História, Ciências, Saúde-Manguinhos, 12*, 117–143.

Fischer, K. W., & Bidell, T. R. (1998). Dynamic development of psychological structures in action and thought. In W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology* (5th ed., pp. 467–561). New York: Wiley.

*Freedman, M. R. (2010). A "healthy pizza kitchen" nutrition education program at a children's health museum. *Journal of Nutrition Education and Behavior, 42*(5), 353–354. doi:10.1016/j.jneb.2010.01.012.

Gardner, H. (1999). *Intelligence reframed: Multiple intelligences for the 21st century*. New York: Basic Books.

*Glick, M. P., & Samarapungavan, A. (2008). Wolves are beautiful and proud: Science learning from a school field trip. *Journal of Museum Education, 33*(2), 199–207. http://www.jstor.org/stable/40479644.

*Hall, T., & Bannon, L. (2006). Designing ubiquitous computing to enhance children's learning in museums. *Journal of Computer Assisted learning, 22*, 231–243. doi:10.1111/j.1365-2729.2006.00177.x.

*Henderson, T. Z., & Atencio, D. J. (2007). Integration of play, learning, and experience: What museums afford young visitors. *Early Childhood Education Journal, 35*, 245–251. doi:10.1007/s10643-007-0208-1.

Hirsh-Pasek, K., Michnick Golinkoff, R., Berk, L. E., & Singer, D. (2008). *A mandate for playful learning in Preschool: Applying the scientific evidence*. Oxford: Oxford University Press.

*Hooper-Greenhill, E., & Moussouri, T. (2000). *Researching learning in museums and galleries 1990–1999: A bibliographic review*. Leicester: Research Centre for Museums and Galleries.

*Hsu, T.-Y., Ke, H.-R., & Yang, W.-P. (2006). Knowledge-based mobile learning framework for museums. *The Electronic Library, 24*(5), 635–648. doi:10.1108/02640470610707240.

Jeffers, C. (1999). When children take the lead in exploring art museums with their adult partners. *Art Education, 52*(6), 45–51.

*Kelly, L. (2007). *The interrelationships between adult museum visitors' learning identities and their museum experiences*. Sydney: University of Technology.

*Krakowski, P. (2012). Museum superheroes. *Journal of Museum Education, 37*(1), 49–58.

*Luke, J. J., Stein, J., Foutz, S., & Adams, M. (2007). Research to practice: Testing a tool for assessing critical thinking in art museum programs. *Journal of Museum Education, 32*(2), 123–136. http://www.jstor.org/stable/40479583.

*Mallos, M. (2012). Collaboration is the key. *Journal of Museum Education, 37*(1), 69–80.

*Martell, S. T. (2008). Of cultural tools and kinds of knowledge: Investigating field trip-based learning about art, culture, and the environment. *Journal of Museum Education, 33*(2), 209–220. http://www.jstor.org/stable/40479645.

*Melber, L. M. (2003). Partnerships in science learning: Museum outreach and elementary gifted education. *Gifted Child Quarterly, 47*(4), 251–258. doi:10.1177/001698620304700402.

*Milutinović, J., & Gajić, O. (2010). Intercultural dialogue in the museum context. *US-China Education Review, 7*(7), 30–42.

*Murriello, S. E., & Knobel, M. (2008). Encountering nanotechnology in an interactive exhibition. *Journal of Museum Education, 33*(2), 221–230. http://www.jstor.org/stable/40479646.

*Palmquist, S., & Crowley, K. (2007). From teachers to testers: How parents talk to novice and expert children in a natural history museum. *Science Education, 91*(5), 783–804. doi:10.1002/sce.20215.

*Puchner, L., Rapoport, R., & Gaskins, S. (2001). Learning in children's museums: Is it really happening? *Curator: The Museum Journal, 44*(3), 237–259. doi:10.1111/j.2151-6952.2001.tb01164.x.

*Rahm, J. (2004). Multiple modes of meaning-making in a science center. *Science Education, 88*(2), 223–247. doi:10.1002/sce.10117.

Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European Journal of Social Theory, 5*(2), 243–263. doi:10.1177/13684310222225432.

*Reisman, M. (2008). Using design-based research in informal environments. *Journal of Museum Education, 33*(2), 175–185. http://www.jstor.org/stable/40479642.

*Rennie, L. J., & Johnston, D. J. (2004). The nature of learning and its implications for research on learning from museums. *Science Education, 88*(4), S4–S16. doi:10.1002/sce.20017.

Semper, R. J. (1990). Science museums as environments for learning. *Physics Today, 43*(11), 50–56. doi:10.1063/1.881216.

*Sung, Y., Hou, H., Liu, C., & Chang, K.-E. (2010). Mobile guide system using problem-solving strategy for museum learning: A sequential learning behavioural pattern analysis. *Journal of Computer Assisted learning, 26*(2), 106–115. doi:10.1111/j.1365-2729.2010.00345.x.

*Tenenbaum, H. R., Prior, J., Dowling, C. L., & Frost, R. E. (2010). Supporting parent-child conversations in a history museum. *British Journal of Educational Psychology, 80*(2), 241–254. doi:10.1348/000709909X470799.

*Tenenbaum, H. R., Rappolt-Schlichtmann, G., & Zanger, V. V. (2004). Children's learning about water in a museum and in the classroom. *Early Childhood Research Quarterly, 19*(1), 40–58. doi:10.1016/j.ecresq.2004.01.008.

*Van Schijndel, T. J. P., Franse, R. K., & Raijmakers, M. E. J. (2010). The exploratory behavior scale: Assessing young visitors hands-on behavior in science museums. *Science Education, 94*(5), 794–809. doi:10.1002/sce.20394.

Vygotsky, L. (1967). Play and its role in the mental development of the child. *Soviet Psychology, 5*(3), 6–18.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.

Weier, K. (2000). *Lessons from an interactive exhibition: Defining conditions to support high quality experiences for young children*. Unpublished Master's thesis, Queensland University of Technology.

*Weier, K. (2004). Empowering young children in art museums: Letting them take the lead. *Contemporary Issues in Early Childhood, 5*(1), 106–116. doi:10.2304/ciec.2004.5.1.2.

Weil, S. (1999). From being about something to being for somebody: The ongoing transformation of the American museum. *Daedalus, 128*(3), 229–258. http://www.jstor.org/stable/20027573.

*Wickens, K. A. (2012). Museums and community—The benefits of working together. *Journal of Museum Education, 37*(1), 91–100.

*Wilde, M., & Urhahne, D. (2008). Museum learning: A study of motivation and learning achievement. *Journal of Biological Education, 42*(2), 78–83. doi:10.1080/00219266.2008.9656115.

*Wöhrer, V., & Harrasser, D. (2011). Playful experiments: Gendered performances in a children's museum. *Science as Culture, 20*(4), 471–490. doi:10.1080/09505431.2011.605925.

*Wolberg, R. I., & Goff, A. (2012). Thinking routines: Replicating classroom practices within museum settings. *Journal of Museum Education, 37*(1), 59–68.

*Wolf, B., & Wood, E. (2012). Integrating scaffolding experiences for the youngest visitors in museums. *Journal of Museum Education, 37*(1), 29–38.

Yoshii, A., Plaut, D. A., McGraw, K. A., Anderson, M. J., & Wellik, K. E. (2009). Analysis of the reporting of search strategies in Cochrane systematic reviews. *Journal of the Medical Library Association, 97*(1), 21–29. doi:10.3163/1536-5050.97.1.004.

*Zimmerman, H. T., Reeve, S., & Bell, P. (2008). Distributed expertise in a science center: Social and intellectual role-taking by families. *Journal of Museum Education, 33*(2), 143–152.