INVESTIGATING VISITORS' LEARNING RELATED TO SCIENCE CENTRE EXHIBITS – A PROGRESS REPORT OF RECENT RESEARCH LITERATURE AND POSSIBLE FUTURE RESEARCH FOCI

Eva Davidsson

SAMMANFATTNING

Forskningsfältet som rör lärande i informella miljöer växter ständigt och under den senaste tiden har antalet artiklar som fokuserar lärande i relation till ett besök på ett science center eller museum ökat kraftigt. Men vilka slutsatser kan man dra när det gäller utställningar och besökares lärande? Vilka metodologiska trender kan man se och vilka framtida forskningsområden kan tänkas utgöra intressanta fält? Denna forskningsgenomgång analyserar och diskuterar olika forskningsstudier som fokuserar besökares lärande och deras interaktioner med utställningar samt studier som utvärderar utställningsmiljöer. Vidare diskuteras trender med avseende på olika metodologiska ansatser samt föreslår framtida forskningsfokus inom fältet.

Nyckelord: Informellt lärande, science center, museer, sociokulturellt perspektiv

INTRODUCTION

The area of research concerning learning and informal settings is constantly growing and has developed further during the last decade. This means that an increasing number of studies aim to explore, for example, visitors' learning and interactions when attending exhibitions, staff members' ideas about exhibit design, or the interaction between formal institutions and informal learning environments. In order to summarise this research, several reviews have been published. For example, Rennie and McClafferty (1996) examine the role of Science and Technology centres (STC) in relation to when and how visitors learn and understand science. The authors conclude that a large number of studies indicate positive attitudes towards visiting STCs and that exhibition environments have educational potential. However, they emphasise the need for improvement when it comes to research focusing on the relation between visitors' learning and exhibition design as well as for broadening the research design and methods, in order to approach the complexity of variables under study.

EVA DAVIDSSON
fil. dr och lektor i utbildningsvetenskap,
Malmö Högskola
Lärande och samhälle, 205 06 Malmö
E-post: eva.davidsson@mah.se

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Eva Davidsson

Hofstein and Rosenfeld (1996) conducted another review, which focuses on the relation between learning science in informal and formal environments and, in particular, how experiences from STC visits could be integrated into school science. The authors conclude that there is a need for further research focusing on how to *effectively blend experiences* from informal and formal settings in order to significantly enhance science learning. A third review by Pedretti (2002) focused on the discussion about how science should be re/presented in exhibitions, particularly with regard to socio-scientific issues and the nature of science. Four key factors in exhibit design, which could enhance visitors' engagement and learning, were recognised: considering visitors' motivation and context, using a constructivist framework, considering multiple intelligences, and the affective domain.

Yet another example of a review is provided by the Committee for learning science in informal environments (National Research Council [NRC], 2009), where the authors identify six different strands of science learning as a means to define appropriate learning outcomes. The authors argue that the strands *Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world and Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science* are particularly relevant to informal learning environments. In addition the committee provides research-based recommendations for how to organize, design and support science learning.

These examples of reviews highlight, in turn, the role of STCs for learning science, the relation between STCs and school science, how science should be presented in order to enhance learning from exhibitions and, different strands of science learning. A common thread in these reviews is the focus on visitors' learning but they also approach exhibition content and design in relation to visitors' learning. This article continues the discussion of our understanding about visitors' learning by highlighting and discussing research studies that aim to describe how visitors' learning is developed when attending exhibitions at science centres and museums. Furthermore, the article aims to analyse these studies with regard to research foci and methodological approaches. This means that research studies aiming to ex-

plore other areas in relation to exhibition environment such as visitors' agendas when visiting exhibitions, profile of the visitors or impact on the environment are not included in this article. Finally, it also outlines possible future research areas within the field of learning and informal settings.

LEARNING AND SCIENCE EXHIBITIONS

The most common approach to research within the field of learning and informal settings is probably the one related to visitors' learning, particularly cognitive learning outcomes, from exhibitions. A number of studies aim to explore what visitors recall, memorize and learn from exhibitions or how students and teachers use the exhibition as a tool for cognitive learning. This approach also includes questions about what impacts the exhibition setting could have on, for example, visitors' ideas about scientific concepts and phenomena or how certain features of the exhibition enhance visitors' learning. According to Rennie (2001), most studies concerning visitors' learning are either *exhibit-related* or *visitor-related*. Exhibit-related studies often seek to explore and evaluate the effectiveness of exhibit content and design in relation to visitors' learning, such as how different exhibit features affect visitors' cognitive learning outcomes. Examples of these studies are discussed in a later section of this article. Visitor-related studies mainly focus on the visitors' behaviour, actions and dialogues, but are usually related to the specific context of the exhibition. The following section explores visitor-related research studies, including both family visitors and visitors in school groups.

Visitor-related research

With regard to school trips, Griffin (2004) argues that (1) the overall educational value of school visits to museums, (2) the impact of preparing for such visits and (3) early studies into the complexity of how different elements may influence students' learning have received the most research attention. In her review, she concludes that the educational value of field trips is equivocal and context specific, but also that preparation significantly enhances learning. Furthermore, she argues that earlier studies usually do not fully address the *complexity of the context* nor do they adequately consider students' and teachers' perceptions and expectations of field trips. Griffin concludes, however, that recent research seems to focus to a greater extent on adult and student conversations.

In contrast, earlier research about family learning explored, to a large extent, visitors' behaviour in the museum setting and concluded, for example, that they tend to behave in predictable patterns during their visits, but also that these patterns are influenced by the physical and social setting (Crowley & Callanan, 1998; Hilke, 1989). One methodological approach in this area involves observing visitors' behaviour in terms of what they are doing and time spent at different exhibits (e.g. Chiozzi & Andreotti, 2001; Korn & Jones, 2000). An assumption in these kinds of studies seems to be that if visitors spend a long time interacting with an exhibit, their learning would be influenced positively (e.g. Sandifer, 1997). From this reasoning it is possible to judge visitors' learning by studying the amount of time spent in the exhibition and at individual exhibits. However, visitors' own preferences and learning experiences are seldom explored in these studies, nor are their conversations while interacting with exhibits.

Thus, exploring visitors' learning by using observations of time spent at an exhibit and what they do seems to be insufficient for increasing our understanding of visitors' learning. More recent research has instead studied visitors' conversations in connection with their actions and interactions while interacting with exhibits. Studies that have investigated the content of the conversations include research by Allen (2002). She concludes that over 80% of the conversation content among 49 pairs of adult visitors could be classified as *learning talk*. Learning talk refers to discussions containing conceptual, perceptual, connecting, strategic and affective talk. Other research by Crowley and Jacobs (2002) focuses on the family group and notes the way in which *parent mediated talk* influences the children's learning. Their results show that more complex discussions, involving explanations, inferences about scale or connections to children's previous experiences enhanced children's factual knowledge.

Siegel, Esterly, Callanan, Wright and Navarro (2007) also investigate parent-child conversations and relate parents' *explanatory talk* and *styles of interaction* with their children to their educational levels. The results reveal that families show similar and rich explanatory conversations independent of the parents' education, but parents with higher levels of education tend to have more directive interaction styles than parents with basic schooling. Another study (Crowley, Callanan, Terebaum, & Allen, 2001) highlights a gender difference in parent-child conversations. Through observations of families with pre-school children, the authors found that boys and girls were equally initiating and engaged in interacting with exhibits, but the parents were more likely to explain casual connections to boys than to girls. This means that the boys heard three times more explanations than the girls.

Several studies since then have explored visitors' conversations and dialogues, but some studies also included other forms of interaction when studying visitors' learning from exhibitions. For example, Rahm (2004, 2012) points to the importance of including *non-verbal forms of interaction* when exploring students' meaning making. She argues that a rich description of students' knowledge development is dependent on both verbal and non-verbal interactions simultaneously.

Ash (2002) argues that one way of increasing visitors' interaction and encouraging learning conversations could be to display complex scientific issues. This means that socio-scientific dilemmas are highlighted from different perspectives, which enhance argumentation rather than giving correct answers. In her research, Ash relates the family conversation to the scientific content of the exhibits and reveals that a *powerful thematic content* is the underpinning for meaning-making conversations. This suggests that providing families with interesting and complex issues to discuss could both enhance learning and bridge differences in ages and expertise. Furthermore, Ash (2004) concludes that, in addition, such family conversations have the potential of enhancing the family members' scientific literacy.

Robertson (2007) also investigates, through interviews and observations of fourth and fifth graders, different factors that could affect and enhance students' shared experiences. According to Robertson, there are several factors which significantly impact and reinforce progress towards a *shared vision* among the group members, including time, communication, understanding others' perspectives, dedication and ownership and the collaborative environment. In her study, students both expressed enhanced scientific learning and developed their views about teaching and learning through negotiations with their peers. This discussion has focused on studies that investigate the significance of enhancing visitors' conversation to support learning. But how do staff members and exhibit designers consider issues about visitors' learning?

Staff members' ideas about visitors' learning

A small part of the research literature examines staff members' ideas about visitors' learning. For example, what approaches or strategies do the staff members use when designing and constructing new exhibitions and what ideas do they express about visitors' learning? Several studies imply that when staff members design new exhibitions, they tend to consider visitors' learning only from the perspective of their own experience and only slightly rely on what is known from research. This is explicit, for example, in the study of Astor-Jack, McCallie and Balcerzak (2007), who explore views of effective professional development by comparing staff members' *language use* at four higher education institutions with the language use of staff at four informal science institutions. Their results suggest that the use of language tends to be more informal, experience-based and individualistic among the staff members at the informal institution and more formal, theory-based and consistent among higher education staff. The authors argue that the informal and experience-based language use of the informal institution staff members could be a result of their personal experiences and discovery of what had worked in communicating with visitors in the past.

The results of this study are in line with the conclusions of Davidsson and Jakobsson (2009), who explore in what ways STC staff members consider visitors' learning when interacting with exhibits. Furthermore, they investigate what *references to knowledge* the staff members use when considering learning, and also what references they employ related to the scientific content of exhibitions. The results from semi-structured interviews reveal that the staff members refer to learning processes differently by distinguishing, for example, organized from non-organized learning and theoretical from practical hands-on learning. A majority of the staff members state that they do not have scientific knowledge about learning, but instead refer to their own personal and professional experiences. However, when discussing the scientific content of the exhibitions, all staff members use references from the scientific community.

According to Davidsson and Jakobsson (2009), there is a risk that an experience-based approach leads to a view where learning is seen to occur only in specific situations. This means that learning may be viewed only as formally organized and that staff members do not consider enjoyment as learning. Another consequence could be that educational issues are seen as an aspect to be considered only after the exhibit is constructed. This is evident when Knutson (2002) ethnographically explore staff members' negotiations and decision-making when planning a temporary art and science exhibition. Her results reveal tensions between the different team members in terms of how to integrate educational material into the exhibition. For example, the curators' vision was to complete the project and then invite educators to add educational material. This vision is also evident in work by Tlili, Cribb and Gewirtz (2006), where exhibit constructors argued that certain aspects, such as equality and diversity policies and practices, could be added by the educators and were not considered as part of exhibit design.

Yet another consequence of an experience-based perspective on learning among staff members can be seen in various studies of guided tours in museums. For instance, Tal and Morag (2007) observed 42 guided student visits at a national history museum and conclude that the tours tend to be curator-centred and the questions are, to a large extent, rhetorical. The guides use a good deal of scientific language but explain scientific words only to a limited extent. Furthermore, the accompanying teachers are involved or used as educational resources to a very low extent. Cox-Petersen, Marsh, Kisiel, and Melber (2003) come to similar conclusions, as the museum staff members in their study tend to present the exhibition content in guided tours in a didactical and authoritarian way. In contrast, Tran (2006) gives a more nuanced image of the work of museum educators. She concludes from her observational study that the educators, while engaged in school group lessons, tend to adapt their pre-planned lessons to the needs, interests and abilities of the students. However, the educators communicate, to a large extent, with the students through initiate-response-evaluation (IRE) patterns (Sinclair & Coulthard, 1975; Lemke, 1990; Mortimer & Scott, 2003) and often fail to let the students articulate their thoughts and ideas.

From this discussion, it seems that staff members tend to consider the scientific content of the exhibitions from a scientific perspective, but refer to learning mainly based on personal experiences. Furthermore, studies imply that exhibit designers tend to regard exhibit content and visitor learning as independent or as separate things, where learning risks being viewed only in terms of how to transfer the scientific content to the visitors. Research also indicates that staff members seem to present exhibitions in guided tours in a monologist and didactic way (e.g. Ash, Lombana & Alcala, 2012). But in what ways is science constituted in exhibitions and how do staff members consider and decide what to include or exclude when constructing new exhibitions?

Exhibit-related research

An important aim of STCs is, according to Association of Science and Technology Centers (ASTC) that visitors will encounter hands-on, interactive exhibits and first-hand experiences with scientific phenomena. Furthermore, the goals of different science exhibitions are educational. Errington, Stocklmayer and Honey-

man (2001) argued that museums and centers, of all kinds, play a key role in the educational infrastructure as they provide learning resources for schools as well as citizens. In order to promote visitors' learning Pedretti (2002) suggests integrating socio-scientific issues into exhibitions. Based on a review, she argues that the scientific content of exhibitions has changed during the past decades from being object-centred and displaying "the wonders of science" towards a more provocative display of science, focusing to a greater extent on socio-scientific issues. Janousek (2000) argues that museums have undergone several major shifts when it comes to the content of exhibitions (e.g. from structures to processes, from parts to the whole, and from 'exact truths' to approximative descriptions and the use of metaphors). He furthermore argues that a new generation of museums will be *context museums*, which will mediate voyages in the history of humanity, and use technical artefacts to explain the development of civilization in order to reveal human knowledge. Bradburne (1998) also stresses the importance of changing the characteristics of exhibitions towards enhancing visitors' creativity, collaborations, and skills of finding, appropriating and using new knowledge.

However, these notions of the *context museum or displaying a more provocative image of science* do not seem to have had an impact on exhibitions generally. Davidsson and Jakobsson (2007) conclude that the most common image displayed at Nordic STCs is *the usefulness of science*. They found that staff members in these institutions, above all, tend to choose to display the scientific aspects of science in society, science in a technical perspective, how modern science is generated and scientific facts, which together serve to emphasise the benefits and use we have of science in our society. Aspects such as controversial issues, values or gender issues were represented to a very low extent in contemporary exhibitions. Similarly, other research (Alfonso & Gilbert, 2008) has also found that science tends to be exemplified through technology and that risks, benefits or ethical considerations are rarely discussed. A possible explanation for these results can be found in Tlili, Cribb and Gewirtz (2006). This study explored staff members' ideas about incorporating equity and diversity politics and practice into science exhibitions and found that this area was not considered to belong to exhibit design. Instead it was considered to be an educational area and consequently should belong to the education department. Another explanation for why exhibitions tend to disregard provocative aspects of science could be the staff members' beliefs about what science an informed public needs to know. Macdonald (1998) argues that staff members' choices of what to include in exhibitions creates *particular kinds of science for the public*, who consequently attribute certain artefacts or activities as belonging to science. But how do staff members, who work with planning and creating new exhibitions, consider the scientific content? Why do they choose to display certain scientific aspects in favour of others?

Davidsson (2009) shows that the staff members in her study, above all, tend to view the scientific content of exhibitions in organisational terms. They focus on the content in relation to their exhibition area; available material or what would be considered as enjoyable. Furthermore, she found that aspects such as the relationships between science and society, politics, and economy, as well as non-consensus explanations in contemporary science, risk being absent or implicit to the visitors. In the study, staff members argue that displaying different explanatory models or ambiguous issues to visitors could lead science institutions to question the credibility of the museum. Along similar lines, Macdonald (1998, 2002) explores staff members' approaches to the content of an art and science exhibition and reveals that not only are staff members' rationales and assumptions not explicit to the visitors, but also that relations between science and societal and political contexts tend to be overlooked by the staff members.

In order to circumvent the tendency of displaying a strongly product-oriented and uni-dimensional view of science, Pedretti (2004, 2012) advocates for issues-based exhibitions. She argues that such exhibitions could serve as a means to address socio-scientific issues, issues related to the nature of science, and, in addition, can promote visitors' dialogue, reflexivity and argumentation. She defines issues-based exhibitions as containing different societal dilemmas, in which visitors are confronted with social issues with scientific content and are asked to suggest solutions (Pedretti, 2012).

Staff members' choices of what to include or exclude in an exhibition thus seems to have an impact on how science is constituted in exhibitions and what *images of science* are communicated. However, there are also indications that sponsors may have an impact on the scientific content of exhibitions. For example, Davidsson and Sørensen (2010) show that sponsors, in many cases, create prerequisites for exhibitions at STCs, and that they also often influence the work of developing new exhibitions both directly and indirectly. Staff members in the study experienced explicit interference by sponsors in the content and design of the exhibitions, who also expressed a demand of being visible in it. The curators also tended to consider implicit demands for what they believed were views of the sponsors.

Exhibitions, artefacts and design

In order to explore visitors' engagement and learning from exhibitions, several studies focus on evaluation of exhibits or describing theoretical starting points for exhibit design. This research focus concerns overall ideas about exhibit design, but can also involve certain specific exhibit features, such as the use of new technology, audio-guides or labels. Concerning overall ideas, Allen (2004) discusses four aspects of exhibit design, which could potentially influence visitors' learning and engagement with exhibits: immediate apprehendability, physical interactivity, conceptual coherence and diversity of learning models. The first factor, immediate apprehendability, refers to a direct understanding of the exhibit's scope, purpose and properties. This factor is essential, according to Botelho and Morais (2006), as exhibits with explicit goals facilitate interaction and, in addition, enhance students' learning. Also Csikszentmihalyi and Hermanson (1995) consider this factor as crucial for activities in the exhibition setting, as it may generate a *flow experience*. A flow experience refers to a situation where a person engages and is completely immersed in tasks without any extrinsic rewards (e.g. good grades

or salary). Accountability and feedback also increase the likelihood of a flow experience (Csikszentmihalyi & Hermanson, 1995).

The characteristics of flow are closely related to other characteristics of exhibits that can also affect visitors' attention (Sandifer, 2003). Sandifer (2003) explores how different characteristics of 61 exhibits affect the attention and holding time of 47 visitors. The results show that technological novelty and open-endedness significantly increase the holding time of interactive exhibits. Technological novelty refers to an exhibit which contains state-of-the-art devices or which illustrates phenomena impossible or laborious for visitors to explore on their own.

However, it seems that it is not only the novelty of technology, but also technology per se, that could have an impact on visitors' learning. Lindemann-Matthies and Kamer (2006) explore, through pre- and post-tests as well as interviews with more than 600 visitors, how the use of interactive touch screens and touch tables affect and enhance visitors' learning. The results are compared to the learning outcomes of a group of visitors who only had access to traditional posters and labels. The authors conclude that a test group of zoo visitors, who were engaged in activities related to indigenous species using touch tables, seemed to experience increased learning compared to those who did not use the touch table. Furthermore, the experimental group scored higher on a post-test both immediately after the visit and after two months. One explanation for these results, the researchers suggest, could be that the specific topic, in this case rare indigenous specie, is specifically attracting and exciting. Another explanation could be the inclusion of entertaining interactivity.

This explanation is supported by Swanagan (2000), as the results of his study suggest that zoo visitors who were engaged in interactive exhibits were afterwards more likely to support conservation than visitors who were only passive spectators. The personal backgrounds or interests of the engaged visitors are, however, not thoroughly discussed. Another study, which investigated computer-based exhibits in a science centre, suggests that such exhibits may encourage visitors to turn their activities into performances and thereby attract other visitors and, in turn, constitute shared experiences (Meisner, vom Lehn, Heath, Burch, Gammon & Reisman, 2007).

Audio guides are another feature used to improve interactivity. Their use, however, is contested. Brown (2002) argues that audio tours could be a major drawback by limiting interactions between visitors and thereby impeding learning. But Heard, Divall and Johnson (2000), who investigate students' learning outcomes in relation to the use of audio-guides, show benefits of their use. Their results indicate a gender difference, as the girls who used the audio-guides seemed more able to facilitate their activity and so improved their result on a post-test, compared to the girls who did not use the audio-guides. In contrast, the boys who used the audio-guides did not show any statistically significant difference on the post-test compared to the non-user boys. However these results are not consistent with Novey and Hall's study (2007) of learning outcomes of audio-guided tours in a cave. Their results do not reveal any statistically significant differences between the 123 audio-guided users and the 131 non-users, on knowledge post-test. Nor do they find any evidence that audio-guides impede social interaction between the visitors as Brown (2002) argues. However, drawing on observations of 700 visitors at seven different sites, Novey and Hall conclude that the non-audio user visitors in the cave tend to consider signs and labels to a large extent, in line with other studies pointing to the positive effect of careful labelling on visitors' learning. For example, Borun (2002) concludes that carefully labelled hands-on exhibits tend to enhance visitors' learning compared to unlabelled exhibits.

Bradburne (2002) argues that differences in visitors' interactions could be contingent on the language used in museum labels. He provides an overview of different label types, such as textual authority, observations, games and problems. Hohenstein and Tran (2007) use this framework as a starting point when studying how different labelling affects visitors' conversations. They employed different information and questions on labels, finding that the question 'why is this here?' seemed to promote more open-ended discussion involving both additional questions as well as explanations among visitors.

There are thus several features that could affect and improve visitors' interaction with exhibits in order to enhance visitors' learning. But there are, according to Allen and Gutwill (2004), risks in designing exhibits with overly complex interactivity and adding too many features, which could impede visitors' learning. They identify five common pitfalls and possible effects on visitors' learning: (1) multiple options with equal salience risk overwhelming the visitors, (2) interactivity by multiple simultaneous users can lead to disruption, (3) interactivity, even by a single visitor, may disrupt the phenomenon being displayed, (4) interactive features can make a critical phenomenon difficult to find, and (5) secondary features can displace visitors' attention from the primary one. It seems that there is a risk of "overloading" exhibits with too many interactive features, but these authors do not discuss whether an exhibit with several possibilities for interaction also may also attract a larger audience. Davidsson (2008), and Jakobsson and Davidsson (2012) takes a theoretical approach starting in a sociocultural perspective on learning (e.g. Cole, 2003; Kozulin, 2003; Säljö, 2005; Vygotsky, 1986; Wertsch, 1991, 1998) and discusses the possibilities of creating exhibits for a diverse audience. By providing the exhibits with several mediational factors it is possible to create rich exhibits that may mediate different thoughts and handle different actions by the visitors.

Whereas Allen (2004), Allen and Gutwill (2004) and Davidsson (2008) concern exhibition design in general, some studies focus on design in relation to teachers and school groups (e.g., DeWitt & Osborne, 2007; Griffin, 1998; 2004). The Framework for Museum Practice (DeWitt and Osborne, 2007) aims to provide staff members with a tool, consisting of a set of factors that could enhance school students' learning from museum visits. The framework contains largely practical guidelines, but it is also possible to find similarities with those provided by Allen (2004) and

Davidsson (2008). For example, DeWitt and Osborne (2007) also emphasise the importance of clearly defined and open-ended exhibits and of personal relevance.

This discussion has taken the exhibition as its starting point and explored what there is to be learnt from research about exhibitions, focusing on both their content and design. It seems that features such as accessible technology and labelling could enhance visitors' engagement and support their conversations when they are interacting with exhibits. The exhibitions' artefacts and design hence constitute important prerequisites for learning. Next, I turn to a consideration of what theoretical assumptions about learning and informal settings are evident in the research literature, and in what ways these theoretical starting points affect methodological approaches. Is it possible to discern methodological trends during the last decade within the area of learning and informal settings?

THEORETICAL AND METHODOLOGICAL APPROACHES TO STUDYING LEARNING AND INFORMAL SETTINGS

As seen in the previous discussion, research within the field of learning and informal settings comprises many different ways of collecting data in order to increase our knowledge of, for example, visitors' learning, staff members' ideas about exhibit design or visitors' purposes in attending exhibitions. In order to approach these kinds of issues, questionnaires, interviews, observations, diaries and focus group interviews constitute crucial tools for researchers. However, these matters of methodological designs involving a theoretical approach to learning and the associated implications for data collection methods seem to be implicit or only vaguely addressed in a large number of studies. Several researchers also highlight and criticise this shortcoming and argue that much research is only descriptive and lacks a theoretical base. For example Schauble, Leinhardt and Martin (1997) and Paris and Ash (2000) emphasise the risk of not being able to make comparisons between different research projects or generalisations. In order to circumvent this problem, several researchers suggest or adopt different theoretical approaches when studying learning and informal environments, such as activity theory (Martin, 2004; Rahm, 2012) or ethnography (Macdonald, 1998).

It does seem, though, that when learning is explicitly addressed through the use of a theoretical framework, a constructivist or a sociocultural perspective is often adopted. For example, Anderson, Lucas and Ginns (2003) suggest the use of a constructivist framework and argue that this approach has merits because of its recognition of prior knowledge and as well as subsequent life experience, which contribute to the transformation of the individual's knowledge. Hein (1999) also advocates a constructivist perspective on learning and informal settings, arguing that the viewer constructs personal knowledge from exhibits and that learning is a constructive act. Based on Hein's framework, Stocklmayer and Gilbert (2002) have designed a theoretical model of visitors' learning from exhibits called 'personal awareness of science and technology' (PAST). To change a visitor's PAST, the exhibit needs to be personally engaging, evoke powerful recall of current understanding and demonstrate an evident relationship with a concept or a phenomenon.

The constructivist perspective on learning also has consequences for choice of research methods. Anderson, Lucas and Ginns (2003) suggest using open-ended questions and concept maps to identify visitors' prior knowledge and knowledge developed from museum visits. Stocklmayer and Gilbert (2002) use interviews in order to reveal learning outcomes from exhibits. However, Davidsson and Jakobsson (2008, 2012) argue that learning, from a constructivist perspective, risks being seen as only intramental (Wertsch, 1998) and individual and not accounting for the social and cultural situations where learning occurs. Furthermore, they argue that there is a tendency for only studying learning outcomes and not taking into account visitors' actions and dialogues. But, Ellenbogen, Luke and Dierking (2004) argue that there is an on going shift of research paradigms towards a sociocultural approach when studying family learning in museums. According to those authors, research, to a greater extent, is focused on conversations, which highlight not only an individual's learning, but also learning at the *family level*, and gives insights into how families construct meaning. But what can be seen as the core of a socio cultural perspective on learning and what implications does this approach have for research methods focusing on learning and informal settings?

One starting point in this approach to studying learning is the importance of considering not only the individual learner, but also the individual in interaction with other individuals (e.g. Cole, 2003). This perspective is evident in several of the research studies reported in this article (e.g. Ash, 2004; Leinhardt, Crowley & Knutson, 2002). However, learning from a socio-cultural perspective also comprises interaction with available tools and artefacts (e.g. Jakobsson & Davidsson, 2012; Piqueras, Wickman & Hamza, 2012; Wertsch, 1998). This perspective is evidenced in Packer and Ballantyne (2005), who observe and compare how 40 solitary and 40 paired visitors engaged in exhibits. They also explore, through interviews, how the visitors consider their learning gains. The results show that both the solitary and paired visitors refer to learning benefits gained from visiting the exhibition, and the authors argue that these findings challenge the supposition that social interaction is more beneficial than a solitary experience for learning from museum visits. However, they do not discuss the potential for learning offered by interaction with artefacts. The solitary visitors presumably interacted with the available tools and artefacts in the exhibition and thereby experienced learning gains.

Davidsson and Jakobsson (2009) take this relationship between the visitor and the exhibit as a starting point for studying learning in exhibitions and suggest that this relationship could constitute the core of a model of how learning arises at STCs. Furthermore, Davidsson (2008) and Jakobsson and Davidsson (2012) argue that the concepts of mediation and appropriation could constitute important tools for increasing our understanding of visitors' learning. They suggests a *model of successive appropriation*, where factors such as the learners' previous experiences as well as exhibit features are considered in order to explore and explain visitors'

interactions with exhibits, curators, and with each other. The exhibit features include, for example, explicating the artefacts' cultural-historical background and intentional introduction of the artefact.

The choice of approaching learning from a sociocultural perspective also brings consequences for data collection methods. If considering that learning occurs during interactions, learning must be explored through actions and dialogues. For example, Ash, Crain, Brandt, Loomis, Wheaton and Bennett (2007) argue that the content of the conversation and dialogic processes need to be studied in tandem in order to fully understand collaborative scientific sense making. They have developed a theoretical framework in order to explore *biological talk over time* to be able to identify different science discourses. The results describe visitors' knowledge development concerning, for example, adaptation or reproduction. Also Evans, Mull and Poling (2002) emphasise the importance of studying visitors' dialogues in relation to displayed objects in museums. They argue that an object-based discourse could play a central role as it focuses on the participation of the object in the cultural and lived history of the visitor. This means that instead of assuming that objects somehow speak for themselves, visitors' actions and voices come to play a central role.

This discussion has mainly highlighted the paradigms of constructivist and sociocultural approaches to learning, although there of course exist other fruitful perspectives. It is, however, possible to conclude that there is increased awareness of the importance of using a theoretical perspective on learning when studying visitors' learning and informal settings. This also means that the relationship between the research questions and the choice of methodological approach tends to become more explicit. There seems to be an increase of studies during the last decade exploring visitors' dialogues and actions within the frame of a sociocultural perspective on learning. But what consequences could this shift of research paradigm bring and how will it affect our understanding of visitors' learning?

CONCLUSIONS: POSSIBLE FUTURE APPROACHES TO RESEARCH IN INFORMAL SETTINGS

The aim of this article has been to discuss research focusing on visitors' learning from exhibitions and the exhibition setting. Furthermore, this article has highlighted research paradigms and methodological approaches within the field of learning and informal environments. From the reviews by Rennie and McClafferty (1996), Hofstein and Rosenfeld (1996), Pedretti (2002) and NRC (2009), it is obvious that visitors hold positive attitudes towards STCs and the authors highlight the educational potential exhibitions carry. They furthermore point to several agendas for future research, such as exploring how science should be represented, what images of science are presented, how visitors perceive science in exhibitions, and how learning experiences from STC visits and school science could be blended effectively.

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But in considering this paper as a progress report, it becomes apparent that some of these areas have been under scrutiny and debate during the last decade. For instance, the scientific content in exhibitions and different images of science has been explored by researchers such as Davidsson and Jakobsson (2007, 2012), Davidsson (2008) and Pedretti (2002, 2004), visitors' perception of the exhibition content has been studied by, for example, Rennie and Williams (2002, 2006). Furthermore, a number of studies have focused on school students' learning, in relation to field trips (e.g. Griffin, 2004; DeWitt & Osborne, 2007). But what trends can be seen in research about learning and informal settings? What possible future research agendas can be discerned from the different studies discussed in this progress report?

This article has discussed several problems springing from having an implicit, rather than explicit, methodological approach when exploring learning experiences from visits to STCs and museums. These problems are increasingly highlighted and there seems to be a rising awareness of these shortcomings. Looking forward, there is a continuing need for the adoption of an explicit theoretical starting point, as well as a need to build on and develop theoretical frameworks and analytic tools, in order to come closer to and increase our understanding of visitors' learning from exhibitions. From this review, there also seems to be a trend towards increasing usage of sociocultural frameworks and towards exploring visitors' actions and dialogues (e.g. Allen, 2002; Crowley & Jacobs, 2002). There remains, however, a shortage of studies, which include exhibition content and available artefacts in the analytic unit of visitors' actions and learning. A possible approach to include exhibition content, design, visitors' use of artefacts, interactions and dialogues could be that of studying the STCs' *learning ecology* (Bronfenbrenner, 1979; Rogoff, 2003).

In future studies, this could mean exploring how interaction affects visitors' learning and, in more detail, exploring how *the level of interactivity* influences learning. This may, for example, involve examining how visitors make use of available artefacts and to what extent and in what ways exhibits mediate actions and dialogues. It could also include investigation of how visitors make use of different language genres and discourses in order to create meaning about the exhibition content and appropriate scientific ideas. There is, furthermore, a need for a wider discussion about what constitutes visitors' learning outcomes. As early as 1990, Semper pointed out that exploration and play in learning processes are essential but often overlooked, and it seems that this remark is still valid today. What different forms of knowledge could be important for visitors' learning? How may we explore and evaluate experience-based, tacit, heuristic, sensitive, or action-based knowledge? How are visitors' agendas and preferences related to different forms of knowledge? What analytic tools do we need?

This article has also emphasised and discussed issues related to school trips and it is possible to conclude that there is still a need for more explicit communication between formal and informal institutions. In order to come closer to and circumvent these gaps, several studies have explored interactions between staff members, students and teachers (e.g. Kisiel, 2005; Tal & Morag, 2007). Other researchers

(e.g. DeWitt & Osborne, 2007) discuss frameworks that may serve as tools for increasing the interactions between schools and STCs. However, Griffin (2004) highlights the dilemma of unprepared field trips in relation to cognitive outcomes. That is, although teachers state that they prepare students for, and follow up after, the visits, these activities, to a large extent, tend to focus on logistical issues only. Thus, an important question for further investigation must be what constitutes this seemingly insufficient communication between STCs and schools? How do staff members perceive the work of teachers and what role does the teacher ascribe to the staff members before, during and after the visits?

Another area for future research concerns the scientific content of exhibitions, what images of science are communicated, and how visitors perceive science and socio-scientific issues in exhibitions. But, as seen above, this is not a new research field, as several scholars have discussed and explored these issues for several years (e.g. Davidsson, 2008; Janosek, 2000; Pedretti, 2002; Rennie & McClafferty, 1996). There are, however, on going disagreements around decisions about the development of an exhibition's characteristics and scientific content. For example, is there really an on going shift from displaying *the wonders of science* towards a *context museum*, or is *the usefulness of science* still a prevailing image? A future research agenda could therefore aim to develop analytic tools to describe and analyse the scientific content and design of exhibitions. Furthermore, it could also attempt to investigate underlying assumptions and explanations of the presented images of science.

This review has discussed recent research literature and pointed to some possible research agendas within the field of learning and informal settings. It is clear that science exhibitions carry educational potential and STCs have come to constitute important societal arenas for science communication and lifelong learning. However, if research about learning at STCs and museums is to contribute to increased understanding, there seems to be a need for deeper discussion about theoretical and methodological issues related to research in this field.

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