A framework for understanding the conditions of science representation and dissemination in museums

Marianne Achiam & Martha Marandino

A framework for understanding the conditions of science representation and dissemination in museums

Marianne Achiam[a]* and Martha Marandino[b]

aDepartment of Science Education, University of Copenhagen, Øster Voldgade 3, 1350 Copenhagen, Denmark; bFaculty of Education, University of São Paulo, Avenida da Universidade 308, Butantan, 05508-040 São Paulo, SP, Brazil

Museums are in a unique position to engage the public in conversations about science topics that matter. However, when we attempt to systematically study the representation and dissemination of science in museums, we are confounded by the numerous and diverse conditions and constraints that influence those processes. As a response, we adapt a framework from the field of science didactics, the framework of didactic co-determination, to the museum context. We illustrate how the framework can be applied to a case of exhibit development to understand the influences that shape the final product. We then offer our perspectives on the framework, and suggest how its utility may go beyond the local application described here.

Keywords: exhibit design; public engagement; levels of didactic co-determination; science museums; visitor experience

Introduction

Science centres, natural history museums, zoos and aquaria (in the following: 'museums') are autonomous institutions, dedicated to public education and located within the complex fabric of society. This means that they are uniquely positioned to engage the public in conversations about topics that matter (Welsh 2005), but also that their efforts to inspire such conversations are the highly diverse products of their institutional cultures as well as the influences of the societies that surround them. Accordingly, when we attempt to study museum communication and dissemination efforts, e.g. in the form of exhibitions, we run into a bewildering array of factors that vary, not only from society to society (understood as nations), but also from institution to institution and even from exhibition to exhibition. Although the diversity is arguably part of the attraction of museum-visiting for the public (Falk and Dierking 2000), it also challenges the field of museum research to find ways of contextualising and analysing it, producing 'observations and vocabulary that can be abstracted beyond the specific cases discussed but that are also of direct relevance to exhibition design' (Macdonald 2007, 158).

One issue that may confound attempts to understand the exhibitions and their diversity is the disjunction between the exhibition itself and the process of creating it. While research on museums has often focused on exhibitions and their effectiveness in promoting certain visitor outcomes, if research should go beyond analysing exhibitions

---

*Corresponding author. Email: achiam@ind.ku.dk

and visitors' experiences, we also need to study the process by which they are created and shaped (Knutson 2002; Macdonald 2002). In other words, the represented and disseminated science content is strongly dependent upon (although not identical with) the process by which that science content was constructed (Bosch, Chevallard, and Gascón 2006). Efforts to understand exhibitions must therefore include efforts to understand exhibition production.

In recent years, a number of studies have taken a process-oriented approach to studying exhibitions (Gouvêa de Sousa et al. 2002; Knutson 2002; Macdonald 2002; Marandino 2004; Mortensen 2010; Simonneaux and Jacobi 1997), investigating the deconstruction and reconstruction of science as it is appropriated and adaptively transformed into an exhibition. One observation that may be made from these studies is of the diversity of the agents that are involved in the occasionally disorganised and sometimes opportunistic process of exhibition development. This process typically does not take place within a single functional area of the museum (e.g. collections, marketing, design, governance or education), and may depend on mission statements and financial strategies as much as it does design policies and pedagogical approaches (Davidsson and Sørensen 2010; Dubuc 2011; Macdonald 2002; Marandino 2004; Mortensen 2010; Welsh 2005). Accordingly, when we attempt to understand the production of exhibitions, we must consider the variety of actors and agents who contribute to that production, including actors and agents who are located beyond the walls of the museum.

In the following account, we construct and illustrate a framework for categorising and contextualising the conditions and constraints that influence the representation and dissemination of science in museum exhibitions. We first introduce a framework from the domain of school-based education research and adapt it to the museum-based education research context. We then present a case of exhibit development and use it to illustrate the use of the framework. Finally, we discuss the framework and its perspectives in light of recent research.

Construction of a theoretical framework

As outlined in the introduction, the point of departure for understanding the way science is represented in exhibitions is the realisation that the *production* and the *product* are disjunctive. That is, the science that goes into an exhibition undergoes a transformation process as it is appropriated from its origin (usually an academic science discipline), adapted to a museum context, and embodied in an exhibition. This observation is similar to the one at the root of math and science *didactics*,[1] where the knowledge of math or science as it exists in the scientific discipline is evidently not in a form that can be directly taught in school. As explained by Fensham, 'after all, the contexts of scientists in which this knowledge is constructed are not the contexts of young learners in school' (2002, 36).

A fundamental didactic phenomenon, then, is that science and math content must be appropriated from its origin, usually the scientific research discipline, and adaptively transformed in order to become teachable and learnable. This process is designated as *didactic transposition* (Chevallard 1991). Although didactic transposition seemingly proceeds in a smooth way from academic discipline to school setting, the process is influenced by a variety of institutional and societal conditions and constraints. These conditions and constraints may be explicit, such as the text of a national curriculum, but

they may also be implicit, e.g. a tradition for presenting certain subjects in certain ways in school textbooks (Clément 2007).

Didactics research, more specifically the Anthropological Theory of Didactics, provides us with a framework, the *levels of didactic co-determination*, to identify and contextualise the conditions and constraints that influence didactic transposition (Chevallard 1999). This framework (Figure 1) consists of a hierarchy of levels that co-determine the construction of content in a school setting. Consider the preceding example of textbooks: In a study of French secondary school biology textbooks, Clément (2007) shows how the typical presentation of animal and plant cells in illustrations is a tradition based in part on a pedagogical rationale, namely that the cells shown are those that are typically used in secondary school microscopy and thus recognisable for the students, and in part on a sociological reason, namely the historical and persistent division of the
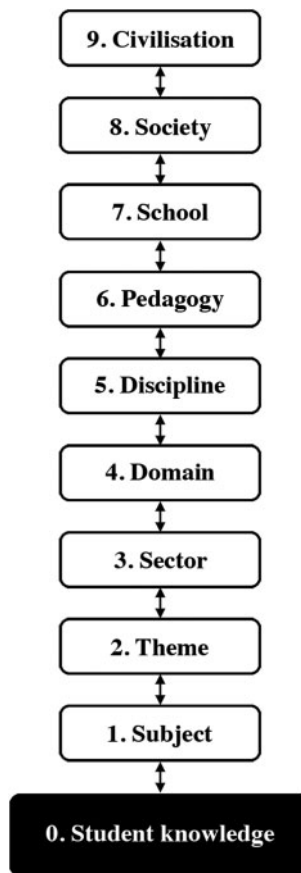

Figure 1.   The levels of didactic co-determination in a school-based science education context (after Artigue and Winsløw 2010). The constraints and opportunities that influence the representation and dissemination of science content in the school setting can be categorised according to their location in the levels of didactic co-determination. The higher levels of co-determination refer to civilization, society, the school and its institutional pedagogy. The lower levels refer to the science content as it is realised at school. The scientific disciplines (physics, biology, geography, etc.) are divided into domains, sectors, themes and subjects defined by the curriculum.

research field of cell biology between animal and plant biologists. The rationale of representing, in textbooks, the cell types that are also typically used in practical microscopy exercises is a constraint that originates at the level of subject (Figure 1, level 1) because the student activity of observing the structure of an animal or a plant cell in a microscope is arguably a quite basic unit of the cell biology curriculum in secondary school. In contrast, the persistent division of the research field of cell biology into animal and plant biologists is a constraint that originates at the level of society (Figure 1, level 8), because the division is based on the history and sociology of the research fields rather than any disciplinary (e.g. biology-related) rationale. In Clément's example, these two constraints work together to maintain the typical representation of cells in biology textbooks, eventually creating an obstacle to students' comprehension of cell differentiation (Clément 2007).

The point is that using the framework as a lens to study the transformation of science in the didactic transposition process can give us a common vocabulary and important insights into why a given science content is taught in a certain way, and why, consequently, it is learnt in a certain way. Further, it allows us to make valid intra- and inter-institutional comparisons by ensuring that the comparisons are made at the same level (Artigue and Winsløw 2010).

Can the framework of the levels of didactic co-determination be brought to bear on the museum exhibition situation? Certainly, the notion of didactic transposition of science resonates with the museum context, and has been applied in several studies to examine the exhibition development process, where this process is designated as *museographic transposition* (Gouvêa de Sousa et al. 2002; Marandino 2004; Mortensen 2010; Simonneaux and Jacobi 1997). But what would be the relevant levels of co-determination in a museum context?

Here, we remind ourselves of a second point made in the introduction, namely that exhibitions are not the products of a single functional area of the museum (Welsh 2005), but are rather produced in the intersection between agents inside and sometimes outside museums (Macdonald 2002). Thus, the higher levels of co-determination from the school context, namely civilisation and society, should arguably be part of a framework adapted to the museum context (Figure 2, levels 9 and 8). For example, Hooper-Greenhill (1999) describes how contemporary museums originated in the historical development that took place in Western culture in Europe and America, culminating with the Enlightenment in the eighteenth century. The positivist stance that characterised these original museum exhibitions is arguably still present in many modern-day museums, thus constituting a condition on how science is produced and disseminated there.

A direct analogy to the institution of the school is the institution of the museum (Figure 2, level 7). Just like schools, museums are institutions dedicated to dissemination and education, and just like schools, many museums are not completely free to act within society, but are bound by external constraints. For example, in order to achieve state recognition and funding, the natural history museums in Denmark must comply with the following paragraph: 'the Danish natural history museums illustrate nature, its development, the contemporary environment and its interplay with humans' (Ministry of Culture 2006, § 8). Other institutions such as science centres may apply for Danish state funding under the VPAC[2] subsidy scheme, which has a number of criteria, e.g.
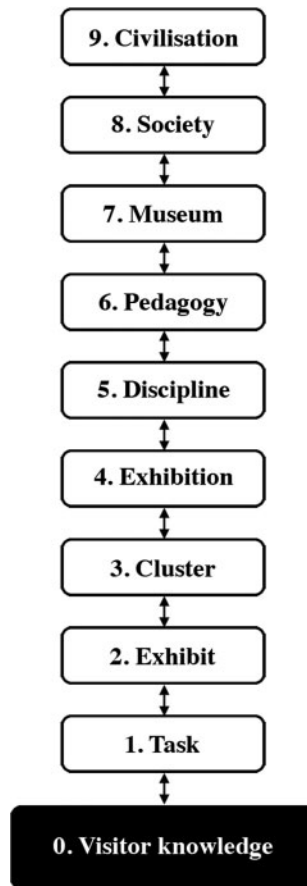
Figure 2. The levels of didactic co-determination as they apply to a museum-based science education context. Just as in a school, the constraints and opportunities that influence the representation and dissemination of science in museums can be categorised by the hierarchy of levels of co-determination. At the higher levels, civilisation, society, the museum institution itself and its institutional pedagogy co-determine the museum's practices. The lower levels refer to the way science content is realised in museums. Here, the scientific discipline or disciplines are usually defined by the structures of exhibition, cluster, exhibit and task.

> The centre must serve as a channel of communication between citizens, educational institutions and research institutions and should accordingly disseminate research results that are relevant to its content area (Ministry of Education 2000).

In the cases described here, the institutions in question have considerable room for manoeuvre. However, it is clear that to secure state funding, they must align their science dissemination activities with conditions originating at the level of society. No doubt, other societies or nations have similar funding schemes for museums.

Just as schools may have certain principles for teaching or pedagogies that transcend the taught disciplines, a museum may have an institutional pedagogy that could be explicit in a mission statement or more implicitly observed. The type of museum does not necessarily define this pedagogy, although the two are obviously connected. For example,

some science centres adhere strongly to the discovery pedagogy founded by Oppenheimer, while others employ a more visitor-oriented pedagogy (Quistgaard and Kahr-Højland 2010). Accordingly, it is important to distinguish between museum and pedagogy and, thus, level 6 is retained as an individual level under the title of 'pedagogy' in the museum context (Figure 2).

Levels 1–5 in the school context are levels that pertain directly to the way science is conceptualised and taught in school. 'Discipline' describes a branch of knowledge unified by a common epistemology and ontology, e.g. biology or physics. Usually, classes in schools are organised by discipline (e.g. biology, physics, chemistry); in museums, however, the disciplines may be more or less explicitly present. In either case, conditions and constraints at the level of discipline are those that pertain to the nature of the particular branch or branches of science as it is realised in the educational context (cf. Artigue and Winsløw 2010). Historically, many natural history museums diversified in the nineteenth century, opening galleries devoted to disciplines such as geology and palaeontology and subdisciplines such as zoology and mineralogy (Delicado 2010). Many of these divisions still exist today, e.g. the National Natural History Museum of Denmark with its three separate museums of zoology, geology and botany. This division arguably imposes constraints on the nature of what can be exhibited in each museum. Accordingly, level 5 is retained under the title of 'discipline' in the museum context (Figure 2), although it refers to a less rigid organisation of science than is the case in school contexts.

The level of 'domain' in a school context (Figure 1, level 4) refers to the conditions that arise from the way subdisciplines (e.g. ecology or cell biology) are organised within a discipline (e.g. biology). In a school context, these may be given by the utilised textbooks or by the allocation of lessons to each domain but, normally, the museum is organised in a different way. Here, the analogous level of organisation is 'exhibition', because within museums, exhibitions are the means of organising and presenting scientific concepts in a way that is accessible to the general public (Alberch 1994). By the same logic, the level 'sector' in a school context refers to a subset of the domain (in the case of the domain of ecology, examples of such subsets could be biodiversity, biological interactions or niche), while the level 'theme' refers to the local organisation, constructed by the teacher, of common themes in a given sector, e.g. different types of biological interactions such as predation and competition. The level 'subject' refers to the smallest units of teaching, e.g. a student exercise in constructing food webs. If we extrapolate the analogy from the preceding, 'sector' becomes 'cluster' in the museum context because clusters, 'mutually exclusive groupings of exhibits that structure an exhibition's content into manageable chunks' (Miles 1988), are the next order of organisation for science content in exhibitions (Figure 2, level 3). 'Theme' in the school context is then analogous to 'exhibit', which is a stand-alone teaching device that typically displays a scientific phenomena or an event (Feher 1990), often as a part of a cluster. Finally, although the exhibit is the smallest conceptual unit the exhibition can meaningfully be divided into, the interactions between a visitor and an exhibit may be further subdivided into a number of tasks, e.g. label-reading, button-pressing or other interactions (Mortensen 2011). Together, these tasks, when accomplished by the visitor, carry the exhibit's intended message, and level 1 (the level of 'subject' in a school context) therefore becomes the level of 'task' in museum context (Figure 2). Finally, the most fundamental level that conditions the representation and dissemination of science in a museum context (as well as in school) is the learner's existing knowledge (Anderson,

Lucas, and Ginns 2003). Therefore, the level of 'student knowledge' in a school context becomes 'visitor knowledge' in a museum context (Figure 2, level 0).

Supporting evidence

In the following sections, we present data from a case of exhibit development that illustrates and substantiates the framework of didactic co-determination as it pertains to the representation and dissemination of science in museum exhibitions. First, we describe the object of study (an exhibit), the informants (four museum staff members involved in the development of the exhibit), other data sources (an internal exhibition planning document) and the method of data collection and analysis. We then give a brief vignette-style account of the development of the exhibit in order to provide the reader with a context for the subsequent section. This account is based on the interview, exhibit and document, but structured in a narrative form by us, the authors, in the interest of clarity and brevity. Finally, we exemplify how constraints and conditions evident in the exhibit development processes can be allocated to various levels of didactic co-determination, using quotes from the interviews as examples.

Object of study, informants and data collection

In the following account, the development of the exhibit *Noises in the Night* is studied. The exhibit was developed in 2007 at the National Natural History Museum of Denmark in Copenhagen. To understand the development process, a semi-structured interview (Kvale and Brinkmann 2009) was carried out with the exhibition department staff members who had been central to the exhibit's development. The interview questions were aimed at tracing the deconstruction and reconstruction of science in the progression from original science content to the finished exhibit. The interview began at the physical exhibit itself, with a point of departure in the concrete, physical installation and its elements. It included questions about the individual elements of the exhibit, the exhibit itself, and the larger context it was located in, i.e. the cluster, the exhibition and the institution. The museum staff members were interviewed as a group by the first author, and the interview took approximately 120 minutes. It was conducted in Danish, recorded, transcribed verbatim and translated to English.

In the following, the staff members from the Natural History Museum are designated as NHM-1 through NHM-4. In addition to the interview and the exhibit itself (described in the following), an internal document regarding the planning of *Noises in the Night* (Claudell 2007) was used as a data source.

Data analysis

In the transcription of the interview, we noted which individual staff member made which comment, but made no further attempt to single out the utterances of the different museum staff members for individual analysis. In the first reading of the transcript, the staff members' utterances were tentatively attributed to a level of didactic co-determination (Figure 2) when relevant. This categorisation was confirmed in the subsequent reading. The data were analysed for both confirming and discrepant situations.

The exhibit *Noises in the Night*

The exhibit *Noises in the Night* (Figure 3) is located in a 50-square-metre space in an exhibition featuring the fauna of Denmark. The exhibition follows a fairly rigid sequence, progressing through the Danish fauna from the last ice age to today, through the space in which *Noises in the Night* was installed, and finally on to various themes of the contemporary Danish landscape, such as night, winter, coast, wetland and urban settings. *Noises in the Night* consists of a three-dimensional, one-to-one scale representation of a campfire with glowing embers, tree logs and stumps arranged in a circle around the campfire, tree trunks reaching from floor to ceiling, a number of taxidermied animals including a bat in flight, a backdrop featuring a sunset, and a soundtrack with the calls of various Danish nocturnal animals as well as the sound of a fire popping and hissing. Banners on the walls feature conversation bubbles with onomatopoeic descriptions of the animal sounds on the soundtrack, e.g. 'huit… huit huit…' as well as the scientific and common names of the animals. The exhibit space is semi-darkened.

The development of *Noises in the Night*

In 2007, the National Natural History Museum decided to participate in the annual culture festival Culture Night in Copenhagen, a night during which cultural institutions such as museums, theatres, libraries, churches and ministries open their doors to visitors and host special events related to their daily activities. The Natural History Museum made the decision to enhance their existing, permanent exhibitions with a series of exhibits related to the theme of 'night'. This choice was related to the theme of the festival, Culture *Night*, but also to the fact that the Museum had recently been successful with after-hours openings during a shorter trial period. During this trial period, the Museum's theme had
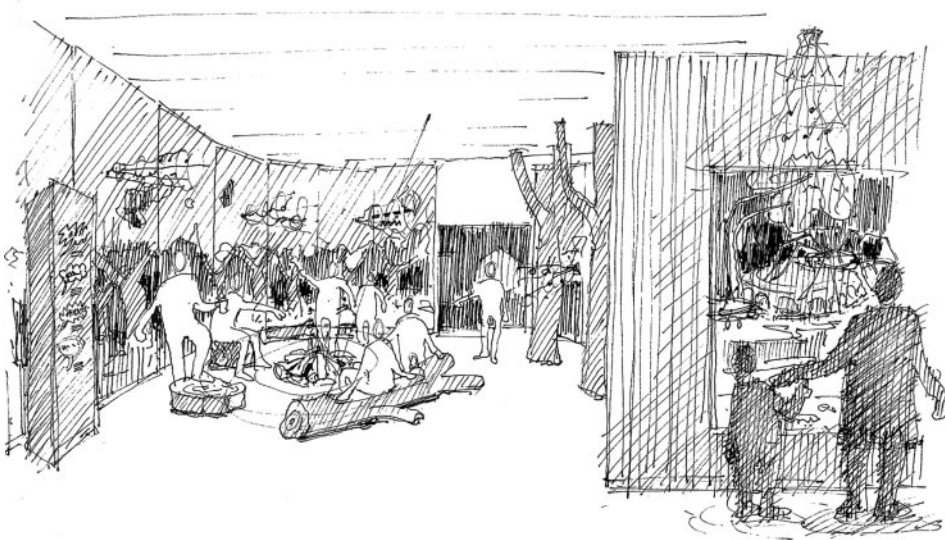

Figure 3.   Sketch of the exhibit *Noises in the Night* at the National Natural History Museum, Copenhagen, Denmark. © 2007 National Natural History Museum. Printed with permission.

been 'Night at the Museum' based on the popular American film from 2006, and this led to the choice of the theme *Noises in the Night*.

Because the three planned exhibits were to be incorporated into the Museum's existing, permanent exhibitions, the individual topics of the exhibits were adapted to the context in which they were to be placed. The physical layout of the exhibits was thus determined by the existing themes on display in the Museum. In the exhibition *North Pole to South Pole*, which features a selection of the various biomes found on Earth, one exhibit was incorporated in the African Savannah area (*Nocturnal Noises on the Savannah*) and one was incorporated into the Asian rain forest area (*Night in the Rain Forest*). The exhibit *Noises in the Night* became part of an exhibition about the Danish fauna from prehistoric times to the present-day cultural landscape. The available space for the exhibit was adjacent to a diorama of a present-day beech wood forest; thus, *Noises in the Night* became about the experiences (especially aural) one might have in a present-day, nocturnal Danish forest.

The elements in the exhibit – a simulated camp fire with glowing embers, simulated woods, logs and tree stumps for prospective visitors to sit on, the sound track featuring the crackle of a camp fire as well as the noises of nocturnal animals – were chosen to create a visitor experience centred on calmness and tranquillity, an atmosphere that was different from that found elsewhere in the museum. The intent was to get the prospective visitor to sit down at the simulated fire, relax and be receptive in a different way. *Noises in the Night* remains a part of the Museum's exhibitions, while *Nocturnal Noises on the Savannah* and *Night in the Rain Forest* were disassembled after Culture Night.

Evidence of the levels of didactic co-determination in exhibit development

The collected data provided evidence of constraints and conditions on the exhibit development process located at the local level, i.e. those that pertained to the specific case of exhibit development; at the institutional level, i.e. those that pertained to the museum as an institution and its established practices; and the external levels, i.e. those that are external to the museum and thus beyond its direct control.

External conditions and constraints: the levels of civilisation and society

The civilisation and society in which a museum is located conceivably have a fundamental influence over its practices. Although we did not find explicit evidence of constraints at the level of civilisation, it could be argued that the institution of the museum is a product of Western culture to the extent that the conditions and constraints originating here become implicit and taken for granted by museum staff. For example, the display of objects and artefacts that can be observed, classified, named, and that present a valid and reliable picture of the world is an activity that has roots in the Enlightenment (Hooper-Greenhill 1999), and remains a core museum activity today (Lord 2002). However, it is probably a relatively rare occurrence for museum staff members to explicitly consider how the epistemological roots of the exhibition as communication form influence their practices.

At the level of society, one obvious condition for the development of the exhibit was the participation of the National Natural History Museum in the event Culture Night, which was critical in the choice of the theme: *Noises in the Night*, as explained by a staff member in the following:

Well, I'll give you the story as it really happened, okay? The story was: 'what are we going to do for Culture Night and for the autumn break?' Okay, we'd had after-hours openings in the winter break, and it was a lot of fun, and it went really well. We'd had a lot of visitors, and it had been a lot of fun. We'd had a theme called 'Night in the Museum' that played off the movie 'Night at the Museum'. So we had to come up with something here. Our manager said 'what about "Noises in the Night"?' And we went with that subject (NHM2).

Here, we see how the societal phenomena of a popular cultural event and a popular film contributed to determining the final exhibit product.

Institutional conditions and constraints: the levels of museum, pedagogy and discipline

At the level of museum, we noted visitor safety issues that pertained to the role of the institution as a provider of cultural, educational and, not least, non-hazardous experiences accessible to the broader public. In *Noises in the Night*, the staff members discussed the layout of the exhibit in relation to the available space:

NHM2: That's what's both good and bad about the exhibit. If people just walk right through the room, they don't get the experience.

NHM4: That's because it's possible to just walk past [the exhibit] if you want to. […] Perhaps, if you couldn't get past the exhibit without interacting with it. If you had to step over the logs, you might get around to sitting down before you made your way through.

NHM1: But then we'd have a lot of technicalities regarding the fire department, wheel chairs, emergency exits…

The museum staff members thus acknowledge the need to provide safe visitor experiences, even though this may entail making compromises with regard to the scientific or educational content. We consider this to be a condition at the museum level, because safety is arguably a museum-wide concern. (Note also the discussion, in the displayed quote, of interaction as a desired objective. This discussion is continued by the museum staff members in the following quote and reflects their considerations about pedagogy.)

At the level of pedagogy, we found several examples of conditions to the development process. One such example is illustrated in the following, in which the conventional pedagogy of museums was bypassed in favour of a more multi-sensory style:

Actually, during the [development] process, this exhibit emerged in a kind of different way. It turned out to actually have a more thoughtful component as well. Because we tried to change the experience to be something more than the passive reception one often meets in museums, right? Instead, you have to participate, and the answer is not necessarily obvious. […] This time, sound was what we decided on. And let me say that this is not about objects that one has to stand around and look at, but it's about using other senses, namely one's ears. Opening up one's ears to what is going on in one's surroundings. Trying, by that route, to reach people's understanding, if I can put it like that (NHM2).

We also found constraints at the level of discipline. In *Noises in the Night*, the staff members had originally installed a taxidermied squirrel in the nocturnal scenery; this scientific error was pointed out to the team by one of the Museum's curators:

> Sometimes, you think you know something, and then you find out that, oops, you were wrong! At one point, there was a squirrel in this exhibition, sitting in a tree. And then we were told, by [the mammal curator] that that animal was not active at night, so we had better remove it! (NHM2).

In this case, the biology expertise of the Museum's mammal curator conditioned the content of *Noises in the Night*, resulting in the eventual removal of the squirrel.

Local conditions and constraints: the levels of exhibition, cluster, exhibit and task

In the conversations with the museum staff members, it became clear that the exhibition within which the exhibit was placed influenced the nature of that exhibit. Indeed, for Culture Night, the exhibit *Nocturnal Noises on the Savannah* was created to fit into the African Savannah area, *Night in the Rain Forest* was created to fit into the Asian rain forest area and *Noises in the Night* was created to fit into an exhibition about Danish fauna (Claudell 2007). Furthermore, the availability of an open space in the exhibition about the fauna of Denmark, between two existing *clusters*, namely 'deciduous forests' and 'night', became a co-determining condition in the decision to create the exhibit *Noises in the Night*:

> NHM1: We had some discussions about where to place the [exhibit], right? In the early stages. Until you said, 'we think it should be placed in the deciduous forest area'. Then we said, 'oh yeah, good idea'.
>
> NHM2: We had a real dead hole there. And we had the beech wood forest, which is really, really nice, and which is located just before the area.
>
> NHM4: And just after it, one enters the 'night' [nocturnal area].
>
> NHM2: So we had this transition from the forest, and then we said, 'let's do the ambience of the woods in the night-time', and that's it.

Thus, co-determined by the content of the clusters immediately surrounding the available exhibit space, *Noises in the Night* was assigned a role as a conceptual transition between them.

When thinking about the exhibit itself in isolation from its surroundings, the staff members emphasised that it represented an attempt to make the prospective visitors 'curious to find out what is happening around them' (NHM2) and to give them an experience (NHM3). When asked to summarise the content of the exhibit *Noises in the Night*, one staff member responded with the following statement: 'sit down and let calmness envelop you' (NHM2). In other words, the scientific content was deliberately downplayed in the exhibit, based on the rationale that if the prospective visitors reached a stage of heightened receptivity, and their curiosity had been stimulated by the noises, they would proceed, on their own, to pursue the more scientific knowledge about the animals producing the noises (NHM1). Thus, the intent to create an alternative to the Museum's other more science-heavy exhibits steered *Noises in the Night* in a more affective direction than was usually the case.

When asked about the connection between the exhibit's elements (campfire, embers, logs, sunset, soundtrack, etc.) and the theme of calmness, the staff members indicated two types of tasks in the exhibit, namely the task of sitting down and relaxing (afforded by the

tree stumps and the campfire), and the act of perceiving the animal sounds on the soundtrack (afforded by the audible soundtrack and the lack of other stimuli):

> NHM1: They are connected in the sense that if you sit at a campfire on a quiet summer night, you become aware of noises because there aren't too many other things. That's it – there aren't too many other things going on. If there was a film with David Attenborough playing, you might not notice the sounds. It's about removing some things, and concentrating on what's left.

> NHM3: If you think about how you sit around a campfire in real life, if you've experienced that, you often just sit there and gaze into the fire and… absorb impressions without needing to speak, right?

The staff members emphasised how the elements of the exhibit constituted an offer for prospective visitors, not a requirement:

> NHM1: It's an offer. You can [interact with the exhibit], but we don't force you to. You are invited, right?

> NHM2: It's an offer. And it kind of needs to be. […] And if [some visitors] decline it, well, that's okay too.

The choice of a campfire and tree stumps as a way of inviting prospective visitors to sit down arguably constrains the efficacy of the exhibit in generating the intended outcome. As described by one staff member, many visitors had been observed simply walking through the area and as a result, not having the intended experience (NHM2).

Finally, although we did not find explicit mention, among staff members' remarks, of conditions and constraints at the level of visitor knowledge, we did consider the science content in *Noises in the Night* to be strongly determined by conditions at this level. The preceding quotes show how the staff members invoke the common human practice of sitting around a campfire and the tranquillity and heightened receptivity that often comes with gazing into a fire, referring to the prospective visitor as the subject. The exhibit targets this common human practice quite deliberately, providing the prospective visitor with objects and scenery from a world familiar to them in order to facilitate their deciphering process. The intent to create these familiar objects and scenery for the prospective visitor could therefore be interpreted as a condition at the level of visitor knowledge.

Discussion

We find the framework of levels of didactic co-determination to have merit in the world of museum research. This finding is based on the theoretical adaptation of the framework to the museum context, and supported by the analysis of the development of the exhibit *Noises in the Night*. In the following, we begin by addressing what could be perceived as shortcomings of the developed framework. We then discuss the implications of the framework for museum research and practice and offer our perspectives.

The unit of analysis

Exhibit development involves a number of different actors with different types of expertise and objectives who are usually engaged at various periods of time in the

development process (Macdonald 2002). Why, then, do we in this account make no attempt to distinguish between the interviewed museum staff members and to determine their individual roles in the development of *Noises in the Night*? The answer to this is that we wish to show how the framework of didactic co-determination can be used as a tool to understand the museographic transposition of science content in a museum, and to detect the presence of conditions and constraints to this process. To use a biological metaphor, we view the museum institution as an ecology in which the production of an exhibit can be seen as the adaptation of an organism (a body of scientific knowledge) to a particular context (the exhibit) through a series of transformations caused by selection (the various constraints and conditions of the institutional environment). Thus, the institutional influences on the *exhibit* were the focus of our inquiry rather than the individual actors and agents who contributed to its development, and who co-constitute the institutional environment.

However, if we were to focus on the individual narratives of actors involved in exhibit development, we would no doubt be able to identify the manifestations of several, if not all, levels of co-determination in these narratives, depending on the position, established alliances, expertise and role of that particular actor. For example, in a school context, the individual teacher usually cannot change the conditions on teaching practices that exist beyond the level of theme (Barbé et al. 2005), while others, such as principals and curriculum developers, do have the power to affect conditions at the higher levels of pedagogy, school or society (Artigue and Winsløw 2010). In the same way, we can imagine how only some museum staff members have the autonomy to affect conditions at the museum level, while at the lower levels of determination, curators *can* affect how and why a certain theme is expressed in an exhibition, or make changes to the way a task is embodied in a prospective exhibit.

The modality of the levels of didactic co-determination

A potentially confusing aspect of the framework of levels of didactic co-determination is the fact that the levels are not of the same modality. That is, how can a level described as 'society' be compared to a level described as 'discipline'? Here, it is helpful to think of the levels of didactic co-determination as constructs that provide a hierarchical context for the conditions that affect museum practice as it is realised in exhibits and exhibitions. As this realisation takes place in a complex and ever-changing interplay between (and beyond) the museum's functional areas (Welsh 2005), we took a pragmatic approach in adapting the framework of didactic co-determination, using the levels of organisation that seem to be commonly identifiable in museums (cf. Lord 2002; Miles 1988). However, these levels are purely social and cultural constructs, to be described and analysed as such, and do not reflect any 'natural' or normative system.

Is the representation of 'canonical science' the ultimate objective for museums?

The reader may have the impression that we consider the representation and dissemination of canonical science content as the most important outcome of a museum's activities. Although this perspective is consistent with the foundational principle of enlightenment of the museum institution (Hooper-Greenhill 1999), today many museums probably prefer to present a more nuanced version of science, including, e.g. controversies and non-expert viewpoints (Laurent 2010).

In any case, the usefulness of the framework presented here is not contingent upon the expert or non-expert acquisition of science by museum visitors. The levels of didactic co-determination may serve as an analytical framework to categorise any phenomena that occur in museums, irrespective of their consistency with canonical science. Again, the framework of didactic co-determination is not normative; it simply systematises the categorisation of didactic phenomena, i.e. phenomena that occur in relation to the creation and dissemination of content to audiences by museums.

Why do we need the levels of didactic co-determination in a museum context?

In the present case, we have shown how the development of a museum exhibit was influenced by conditions and constraints that originated at a variety of levels and that manifested themselves in a variety of ways. Some of these conditions and constraints were clearly present and easily identifiable by the actors involved in the development of the exhibit, while others were subtler and thus not immediately recognised by the respondents. We conjecture that any case of science representation and dissemination in an institution such as a museum is subject to as idiosyncratic and complex a constellation of conditions as was the case in *Noises in the Night*, and propose the framework of levels of didactic co-determination as a means to categorise the conditions of that process without reducing their complexity.

In this sense, the framework responds to the call for a more inclusive perspective of exhibition design made by Schauble (2002), who argues that the unit usually considered by exhibition designers is the exhibit or the gallery rather than the museum, resulting in epistemological inconsistency, an inconsistency which may lead to unintended learning outcomes among visitors. Similarly, a holistic view of museums and their dissemination activities was advocated by Welsh (2005), who emphasised that the work of creating and presenting content involves all levels of museum practice. Here, the levels of didactic co-determination play a role: By offering a hierarchical structure in which the numerous conditions and constraints of content creation, dissemination and acquisition can be organised, the framework allows us to understand how the institutional culture of the museum, as well as the culture that surrounds it, permeates museum activities from the micro to the macro level. To paraphrase Welsh (2005, 103), it allows us to characterise the qualities of the museum that influence its efforts to put ideas into practice.

Extending this line of reasoning, we suggest that the applicability of the framework of didactic co-determination is not limited to the museum practice of designing exhibits; indeed, many other activities of science representation and dissemination take place in museums that can be analysed and understood using the framework. For example, the phenomenon observed by Cox-Petersen et al. (2003) of the lecture-based, non-interactive pedagogy of museum docents as the possible product of a traditional natural history museum archetype is an example of a case that could be specifically analysed and possibly remedied using the framework.

Moreover, the utility of the framework of levels of didactic co-determination is not limited to local applications where phenomena within single institutions are analysed. The scope of the framework allows us to go further, inquiring about the phenomena that extend beyond the sphere of a single museum. For example, the world of museum research and practice has long called for a means to understand and eventually bridge the gap between schools and museums (e.g. DeWitt and Osborne 2007; Griffin 2004; Tal, Bamberger, and Morag 2005; Tal and Morag 2007). We propose the levels of didactic

co-determination as a way to frame investigations into the interactions between schools and museums, allowing us to ask accurate questions about the origins and manifestations of didactic phenomena that arise from this interaction, and equipping us with the knowledge to address them.

Final remarks

In conclusion, we find that the framework of levels of didactic co-determination has considerable merit not just as a means to categorise and understand the conditions of science representation and dissemination in exhibit production in individual museums, but also as a means to understand phenomena that occur in the science representation and dissemination in other types of museum practices as well as in the interactions between institutions. It is our hope that the framework will be used to aid the theorisation and systematisation of research into museums and their practices, thereby furthering the ultimate goal of supporting science learning in museums.

Acknowledgements

Notes

1. In the continental European tradition, 'didactics' refers to the study of teaching-learning systems that aim to disseminate specific content to certain groups of learners. Didactic phenomena occur during any undertakings planned and carried out with the intention of disseminating something to someone. They are thus not limited to schools, but occur in many other arenas such as, e.g. museums.
2. VPAC is an abbreviation of VidensPædagogisk AktivitetsCenter, which translates into Pedagogical Activity Centre.

Notes on contributors

Marianne Achiam (née Mortensen) is an Assistant Professor at the Department of Science Education, University of Copenhagen. She has an M.Sc. in Biology and a Ph.D. in Museum Didactics. Her research interests include science and particularly biology dissemination in informal contexts such as museums, science centres, zoos, aquaria and botanical gardens. She is the coordinator of the Departmental research group on science education in informal settings.

Martha Marandino is an Associate Professor in the Faculty of Education at the University of São Paulo /FEUSP, Brazil. She graduated in Biology and has an M.Sc. and Ph.D. in Education. Her research focuses on science museum education, science education and science communication. She is the coordinator of the Study and Research Group on Non Formal Education and Science Communication/GEENF/FEUSP (www.geenf.fe.usp.br).

References

Alberch, P. 1994. "The Identity Crisis of Natural History Museums at the End of the Twentieth Century." In *Towards the Museum of the Future*, edited by R. Miles and L. Zavala, 193–198. London: Routledge.

Anderson, D., K. B. Lucas, and I. S. Ginns. 2003. "Theoretical Perspectives on Learning in an Informal Setting." *Journal of Research in Science Teaching* 40 (2): 177–199. doi:10.1002/tea.10071.

Artigue, M., and C. Winsløw. 2010. "International Comparative Studies on Mathematics Education: A Viewpoint from the Anthropological Theory of Didactics." *Recherches en Didactique des Mathematiques* 30 (1): 47–82.

Barbé, J., M. Bosch, L. Espinoza, and J. Gascón. 2005. "Didactic Restrictions on the Teacher's Practice: The Case of Limits of Functions in Spanish High Schools." *Educational Studies in Mathematics* 59 (1–3): 235–268. doi:10.1007/s10649-005-5889-z.

Bosch, M., Y. Chevallard, and J. Gascón. 2006. "Science or Magic? The Use of Models and Theories in Didactics of Mathematics." *Proceedings of the Fourth Congress of the European Society for Research in Mathematics Education*, Sant Feliu de Guixols, Spain, February 17–21, 2005, 1254–1263.

Chevallard, Y. 1991. *La transposition didactique: Du savoir savant au savoir enseigné* [Didactic Transposition: From Scholarly Knowledge to Taught Knowledge]. Grenoble: La Pensée Sauvage, Editions.

Chevallard, Y. 1999. "L'analyse de pratiques professorales dans la théorie anthropologique du Didactique [The Analysis of Teacher Practices According to the Anthropological Fheory of Didactics]." *Recherches en Didactique des Mathematiques* 19 (2): 221–266.

Claudell, P. 2007. *Lyde i natten [Noises in the Night]*, 1–8. Copenhagen: National Natural History Museum.

Clément, P. 2007. "Introducing the Cell Concept with Both Animal and Plant Cells: A Historical and Didactic Approach." *Science & Education* 16 (3–5): 423–440. doi:10.1007/s11191-006-9029-7.

Cox-Petersen, A. M., D. D. Marsh, J. Kisiel, and L. H. Melber. 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.

Davidsson, E., and H. Sørensen. 2010. "Sponsorship and Exhibitions at Nordic Science Centres and Museums." *Museum Management and Curatorship* 25 (4): 345–360. doi:10.1080/09647775.2010.525399.

Delicado, A. 2010. "For Scientists, for Students or for the Public? The Shifting Roles of Natural History Museums." *Journal of History of Science and Technology* 4: 1–20.

Dewitt, J., and J. Osborne. 2007. "Supporting Teachers on Science-Focused School Trips: Towards an Integrated Framework of Theory and Practice." *International Journal of Science Education* 29 (6): 685–710. doi:10.1080/09500690600802254.

Dubuc, É. 2011. "Museum and University Mutations: The Relationship between Museum Practices and Museum Studies in the Era of Interdisciplinarity, Professionalisation, Globalisation and New Technologies." *Museum Management and Curatorship* 26 (5): 497–508. doi:10.1080/09647775.2011.621734.

Falk, J. H., and L. D. Dierking. 2000. *Learning from Museums: Visitor Experiences and the Making of Meaning*. Walnut Creek, CA: Altamira Press.

Feher, E. 1990. "Interactive Museum Exhibits as Tools for Learning: Explorations with Light." *International Journal of Science Education* 12 (1): 35–49. doi:10.1080/0950069900120104.

Fensham, P. J. 2002. "Science Content as Problematic – Issues for Research." In *Research in Science Education – Past, Present, and Future*, edited by H. Behrendt, H. Dahncke, R. Duit, W. Gräber, M. Komorek, A. Kross, and P. Reiska, 27–41. Dordrecht, The Netherlands: Kluwer Academic.

Gouvêa De Sousa, G., M. E. Valente, S. Cazelli, F. Alves, M. Marandino, and D. Falcão. 2002. "A Study of the Process of Museographic Transposition in Two Exhibitions at the MAST (Museu de Astronomia e Ciências Afins)." In *Evaluation: Multipurpose Applied Research*, edited by C. Dufresne-Tasse, 108–124. Québec: Éditions MultiMondes.

Griffin, J. 2004. "Research on Students and Museums: Looking More Closely at the Students in School Groups." *Science Education* 88 (Suppl. 1): S59–S70. doi:10.1002/sce.20018.

Hooper-Greenhill, E. 1999. *The Educational Role of the Museum*. 2nd ed. London: Routledge.

Knutson, K. 2002. "Creating a Space for Learning: Curators, Educators, and the Implied Audience." In *Learning Conversations in Museums*, edited by G. Leinhardt, K. Crowley, and K. Knutson, 5–44. Mahwah, NJ: Lawrence Erlbaum.

Kvale, S., and S. Brinkmann. 2009. *Interviews: Learning the Craft of Qualitative Research Interviewing*. 2nd ed. Thousand Oaks: Sage.

Laurent, B. 2010. "Technologies of Representation: Representing Nanotechnology and Society." In *Science Exhibitions: Curation and Design*, edited by A. Filippoupoliti, 178–208. Edinburgh: MuseumsEtc.

Lord, B. 2002. "The Purpose of Museum Exhibitions." In *The Manual of Museum Exhibitions*, edited by B. Lord and G. D. Lord, 11–25. Walnut Creek: AltaMira Press.

Macdonald, S. 2002. *Behind the Scenes at the Science Museum*. Oxford: Berg.

Macdonald, S. 2007. "Interconnecting: Museum Visiting and Exhibition Design." *CoDesign* 3 (S1): 149–162. doi:10.1080/15710880701311502.

Marandino, M. 2004. "Transposition or Recontextualisation? On the Production of Knowledge in Education in Science Museums." *Revista Brasileira de Educação* (26): 95–108. doi:10.1080/15710880701311502.

Miles, R. S. 1988. *The Design of Educational Exhibits*. London: Routledge.

Ministry of Culture. 2006. Museumsloven [The Museum Bill]. Lovbekendtgørelse nr. 1505 [Executive Order No. 1505].

Ministry of Education. 2000. Tildelingskriterier [Criteria for Allocation]. http://www.uvm.dk/Uddannelser-og-dagtilbud/Paa-tvaers-af-uddannelserne/Puljer/Videnspaedagogiske-aktivitetscentre/Tildelingskriterier.

Mortensen, M. F. 2010. "Museographic Transposition: The Development of a Museum Exhibit on Animal Adaptations to Darkness." *Éducation & Didactique* 4 (1): 119–137.

Mortensen, M. F. 2011. "Analysis of the Educational Potential of a Science Museum Learning Environment: Visitors' Experience With and Understanding of an Immersion Exhibit." *International Journal of Science Education* 33 (4): 517–545. doi:10.1080/09500691003754589.

Quistgaard, N., and A. Kahr-Højland. 2010. "New and Innovative Exhibition Concepts at Science Centres Using Communication Technologies." *Museum Management and Curatorship* 25 (4): 423–436. doi:10.1080/09647775.2010.525408.

Schauble, L. 2002. "Cloaking Objects in Epistemological Practices." In *Perspectives on Object-centered Learning in Museums*, edited by S. G. Paris, 235–241. Mahwah, NJ: Lawrence Erlbaum.

Simonneaux, L., and D. Jacobi. 1997. "Language Constraints in Producing Prefiguration Posters for a Scientific Exhibition." *Public Understanding of Science* 6 (4): 383–408. doi:10.1088/0963-6625/6/4/005.

Tal, R., Y. Bamberger, and O. Morag. 2005. "Guided School Visits to Natural History Museums in Israel: Teachers' Roles." *Science Education* 89 (6): 920–935. doi:10.1002/sce.20070.

Tal, T., and O. Morag. 2007. "School Visits to Natural History Museums: Teaching or Enriching?" *Journal of Research in Science Teaching* 44 (5): 747–769. doi:10.1002/tea.20184.

Welsh, P. H. 2005. "Re-configuring Museums." *Museum Management and Curatorship* 20 (2): 103–130. doi:10.1080/09647770500302002.