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# Dinosaurs on Display and Dissemination of Paleontology

## – An exploration of 'Science in the Making' in Exhibition Design


PhD Thesis
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# Dinosaurs on Display and Dissemination of Paleontology

## – An exploration of ‘Science in the Making’ in Exhibition Design

This dissertation is dedicated to my Grandmother

Inger Lauretta Estrup

who took me to my first dinosaur exhibition

and who almost lived to see the completion of this PhD

## Acknowledgements

During my extended PhD period, I have had the pleasure of no less than four supervisors, with each their different roles in the process.

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Last, but not least, thank you to all the respondents of my empirical studies, and especially to Geocenter Møns Klint and Experimentarium for inviting me to participate in the design processes of the two dinosaur exhibitions that were later to become the subject matters of my PhD studies. Now, who would have thought – and what comes next?

Thank you to all my friends – and not least, my kids – for having been patient with me, especially in the last year of writing, and for constantly reminding me that work is not everything (and for not allowing it to become so!).

With gratitude…

Eliza Jarl Estrup

## Abstract

Dinosaurs have always had the ability to fascinate. Even so, paleontology and its origin in natural history is not currently being acknowledged as content matter by the educational system, who frequently portrays science as a monolithic and experimental endeavor. In current dissertation, I present the unique qualities and educational significance of paleontology in especially the out-of-school context of museum exhibitions, and make a case for its reintroduction to the educational system as a whole. I additionally investigate the popularity of dinosaurs in exhibitions, by asking a number of decision-makers behind recent dinosaur exhibitions, on which grounds they chose dinosaurs as their displayed content.

Paleontology holds particular qualities regarding the dissemination of authentic scientific inquiry (in addition to traditional displays of authentic objects – fossils). As such, inquiry-based activities and documentation of 'science in the making' rather than 'ready-made science' are on the rise in the dissemination of paleontology in exhibitions. The middle section of current dissertation investigates the development and design process of such a 'science in the making' exhibition, and subsequently the visitor outcomes of the resulting exhibition - in comparative analysis with a second 'science in the making' dinosaur exhibition. Qualitative and quantitative studies in triangulation suggest that the ontological status of 'science in the making' has an enhancing effect on *scientific literacy* in visitors, albeit differences in the design strategy were detected in correspondence with the nature of the institution in question. The museological design strategy reflects an inductive approach with anchorage in objects and disciplinary features, whereas the design strategy of science centers reflects a deductive approach with anchorage in *discovery pedagogy* and hands-on exhibits.

The final section of the dissertation integrates the design strategies into a practical evidence-based design model, based on co-determinative levels found to have been of influence to the design process, and uses a case study of an inquiry-based exhibit element as an example of its application. The design model is applicable to the design process of 'science in the making' exhibitions, and it is developed with the intention of supporting collaborative efforts between theorists and practitioners within exhibition design in the future.

## Abstract in Danish

Dinosaurer har altid haft evnen til at fascinere. Alligevel er palæontologien og dens naturhistoriske ophav ikke anerkendt som undervisningsfag i det officielle uddannelsessystem i dag, hvor videnskab ofte portrætteres som en monolitisk og udelukkende eksperimentel bestræbelse. I denne afhandling præsenterer jeg de unikke faglige kvaliteter som palæontologien indeholder, med særligt henblik på de uddannelsesmæssige egenskaber – ikke mindst i forhold til uformelle læringssteder som museumsudstillinger. Jeg undersøger også dinosaurernes store popularitet som udstillingsmateriale, ved at interviewe en række beslutningstagere bag nuværende eller nylige dinosaurudstillinger.

Palæontologien indeholder særlige kvaliteter i forhold til formidling af autentiske videnskabelige situationer (foruden den traditionelle fremvisning af autentiske objekter – fossilerne). Derfor er inquiry-baserede aktiviteter og dokumentation af den videnskabelig proces (science in the making) fremfor videnskabelige produkter (ready-made science) i fremgang i formidlingen af palæontologi i udstillinger. Denne afhandlings midterste sektioner undersøger såvel design-processen bag en sådan 'science in the making' udstilling, som gæsternes efterfølgende udbytte i den færdige udstilling i form af en komparative analyse med en tilsvarende proces-orienteret dinosaurudstilling. En triangulering af kvalitative og kvantitative studier peger på at den ontologiske status af 'science in the making' har en positiv effekt på de besøgenes videnskabelige kompetence (scientific literacy), selvom forskellige designstrategier blev påvist i relation til den institutionelle baggrund for udstillingerne. Den museologiske designstrategi reflekterer en induktiv tilgang til stoffet, med udgangspunkt i disciplinen og objekterne, hvorimod en deduktiv tilgang, med udgangspunkt i pædagogiske principper (fx hands-on) reflekteres i designstrategierne for science centre.

Det sidse afsnit integrerer disse designstrategier ind i en praktisk evidensbaseret designmodel, baseret på påviste co-determinations-niveauer fra den studerede design-proces, og med et case-study af et inquiry-baseret udstillingselement som praktisk eksempel. Designmodellen kan anvendes i udviklingen af 'science in the making' udstillinger, og er desuden tænkt som et redskab i styrkelsen af samarbejdet mellem teoretikere og praktikere indenfor udstillingsdesign i fremtiden.

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# Chapter 1
# Introduction

## 1.1 My personal motivation

A PhD study on dinosaur exhibitions? The reason for such a peculiar choice of research topic might be found in my earliest childhood. Back then, a dinosaur exhibition on the local town museum awoke what was to become a lifelong fascination with the ancient dinosaurs and their world in me, and what was to become the reason I later decided to become a paleontologist when I grew up. I met countless skeptical responses on that decision throughout my early years, but they each only made me more stubborn on the case. At the age of 18, I managed to find the first dinosaur fossil of my country, the tooth of a *Dromaeosaurides bornholmensis* (named after the island where it was found), and this finding introduced me to the small community of paleontologists in Denmark.

I subsequently enrolled at biology at the University of Copenhagen and followed all the (few) classes that existed on paleontology and sedimentology at the time – mainly from geology. I even spent all my summer holidays on excavations around Europe and took a semester at the University Complutense of Madrid (where a full Master degree in Paleontology was offered), as one of the only places outside the US and Canada). Over the years, I made close friends with the growing community of paleontology in Portugal, and later one of them became the supervisor of my Master thesis.

But when I finished my thesis on dinosaur metabolism in 2011, something else had also happened to me. I had been introduced to the world of science centers. Working as a disseminator at the Experimentarium in Copenhagen, I was beginning to see the value of science dissemination of a different kind than the classic classroom exercises I knew from school and university. After the completion of my Master degree, I spend most of the first year in China, as the director of a small excavation in the famous area of the feathered dinosaurs in Liaoning (Xu, 2006). The excavation did not prove overly successful, but during my time there, my former workplace, Experimentarium, and additionally a geo-science center from the small island of Møn (Geocenter

Møns Klint) contacted me. They both proposed that I help them design new dinosaur exhibitions, and – in the case of Geocenter Møns Klint – that I participate in a dinosaur expedition to Greenland. This was a turning point for me! Working with exhibition design in those two exhibitions, I discovered an even greater satisfaction than working with fossils and bones: Making the world of these ancient animals come alive and sharing it with visitors!

In the meantime, my experience was that paleontology at the university level was slowly going extinct (I will discuss this further in the following chapter). The courses and researchers of the classic discipline of paleontology (traditionally located at geology), were being gradually replaced by more modern subjects such as ancient DNA, molecular soft-tissue studies on ancient color pigments, blood cells, etc. (located at departments of biology). Hence, less and less financial support was being offered to the traditional study of dinosaur bones and fossils (which are too old to find traces of DNA and soft-tissues). In contrast, more and more natural history museums and science centers convergently expressed a renewed interest in acquiring dinosaurs for their exhibitions – many of them even prioritizing to participate in expeditions themselves and including the excavation process in their dissemination strategy (see chapter 3).

These two trends - the gradual disappearance of classical paleontology from academia and the gradual increase of interest in paleontology and dinosaurs in science centers and museums - sparked my interest in the survival of paleontology as a discipline within science education. Moreover, in the revival of the exhibition format as an alternative arena for this purpose, I was remembering the beginning of my own interest in science, taking place not in school – but in a dinosaur exhibition!

This is how I suddenly found myself in the field of science didactics - a field I had never touched before, and which opened completely new doors into the understanding of my old discipline of paleontology for me. As a complete novice on the subject, I enrolled at an industrial PhD project studying the role and relevancy of paleontology and dinosaurs in exhibition design, as well as the didactic transposition of knowledge in out-of-school contexts, and the various factors of influences on as well the design process as the learning outcomes from the perspectives of science didactics. The concepts will all be defined and introduced in the theoretical framework, but first let us take a look at my personal PhD journey, and where it left me.

## 1.2 My PhD journey (and unique insider role)

As a paleontologist I was, as mentioned, invited to participate in the design process of the dinosaur exhibitions of as well the Experimentarium as the Geocenter Møns Klint as an external consultant in 2012-2013. In the process, I noticed several commonalities – most importantly the choice of disseminating the scientific process behind paleontology – but I also noticed many differences, not least in the institutional approach to the disseminated content. My experience prompted a desire to investigate the mechanisms behind these differences and similarities. Moreover, I was interested in the unique qualities of paleontology making dinosaurs so repeatedly chosen for exhibition contexts, as we will investigate further in the first section of the dissertation (see the NorDina manuscript).

Since paleontology was my own field of study, and I myself participated in the design process of the exhibitions of study, I was also aware that I would play a complex insider role in the various study paths within the investigation. Being a double insider (in as well the scientific discipline as the exhibitions of study), could potentially bias data in the direction of an artificially enhanced enthusiasm amongst respondents. Oppositely, it could also provoke a reaction of defense, if my co-exhibition-designers should feel subjected to surveillance or critique, as was experienced by a similar double insider study within geography by Adriansen and Madsen (2009). However, being an insider also prompts certain advantages, including intimate prior knowledge about as well content as context of the subject matter, again – of course – with the potential risk of being subjected to the bias of personal preconceptions of outcome. This risk is however not unique for insider studies, and in the case of my investigation, I find that the advantages of having been part of the entire process of study myself – from excavating the fossils to designing their exhibition and planning its evaluation – to a high extend exceeds the potential disadvantages of bias. In the following, I will account for which research questions my insider knowledge prompted me to investigate.

## 1.3 Objectives and research questions

My overall objective with the project was to investigate the unique features of paleontology resulting in the frequent use of dinosaurs in science dissemination of exhibitions, which I experienced in the time that followed my Master Degree in paleontology. I initially proposed that the ontological strategy of disseminating 'science in the making' (versus ready-made science) – that I observed in as well Experimentarium as Geocenter Møns Klint – could act as mediator between the disciplinary knowledge and the non-scientific visitor, and that such an exhibition visit might even have a positive influence on the scientific literacy in visitors, if correspondingly designed. Ultimately, as an industrial PhD student, it was also in my interest to develop a practical design model for the discipline-specific dissemination of natural history (exemplified by paleontology), and its successful implementation into exhibition design, potentially resulting in the derived, above described, learning outcomes.

> **Research question 1**: In what way is natural history and the discipline of paleontology different from other branches of science in terms of disciplinary and educational qualities? How are such qualities relevant for exhibition dissemination, and how are they best implemented in the dissemination strategy?
>
> **Research question 2**: Which factors affect the design process of exhibitions, and how can such a design process be optimized so that the integration of a specific disciplinary knowledge and the exhibit elements allow visitor outcomes to correspond to as well the disciplinary potential as the original designer goals? What kind of strategy can be applied to achieve such goals?
>
> **Research question 3**: How does the ontological status of paleontological content matter (science in the making or ready-made science) influence the transposition of scholarly knowledge into content knowledge in an exhibition context, and how can this ontological status influence scientific literacy in visitors?

## 1.4 Informal and out-of-school learning sites

My exhibitions of study and their respective institutions belong to the European museological tradition originally rooted in the study and storage of collections of objects, but now largely dedicated to public education (Achiam and Marandino, 2014). The museological tradition has in time developed into a wide institutional array of dissemination strategies with or without objects, including the traditional museum (with the original emphasis on objects), science centers, geocenters and planetariums (with emphasis on the disciplinary phenomena of science in general, geology or astronomy respectively). The institutional differences between the traditional museum and the science center will be elaborated further in Chapter 3. Common to those institutions, however, is their status of belonging to the ‘informal’ out-of-school context of the public educational system. Increasing efforts have been made recently to fill out the gap between formal and informal science learning (Avraamidou and Roth, 2016), and with exhibition visits arguably being located in the intersection between those two, a definition will be needed in the further discussion of the matter.

Andersen and Ellenbogen (2012), describe the dichotomy of the term ‘informal learning sites’ as 1) The notion of informal learning constituting all learning not taking place in ‘formal’ education system of school, high school, university, etc. including learning from museum visits, internet browsing and even random events of everyday life. 2) The notion of informal learning as learning taking place only in ‘non-designed’ settings and correspondingly not including museums and science centers with exhibitions designed with specific learning outcomes as part of their disseminative goals. In the present study, I will consider the investigated exhibitions as part of the informal learning system, regardless of their pre-designed ontology, but to avoid confusion regarding the definition of the term, the more accurate term out-of-school learning will be applied when needed.

In spite of obvious differences between ‘school’ and ‘out-of-school’ settings (as for example ‘out-of-school’ representing free-choice learning (Falk, 2001 and 2006; Bells *et al.*, 2009) and un-controllable trajectories of the learner, design-based learning sites still in many respects parallel those of design-based learning in the ‘formal’ education system, qua the nature of the design process. Therefore, it makes sense to use some of the same evaluation tools to analyze the learning outcomes and compare them to the original goals of the learning institution (Mortensen and Quistgaard, 2011; Achiam and Marandino, 2014).

The tools I use in my investigation of such a design process and its outcomes belong to the European tradition of *science didactics*, originating from the philosophy of *constructivism*. This school of philosophy takes its point of departure in the notion of the learner being *constructed* of various layers of prior knowledge or experiences, rather than being a ‘blank slate’ or a ‘passive recipient of knowledge’ (Achiam, 2013) as was widely accepted in the 16$^{th}$ and 17$^{th}$ centuries, where the formal educational system was originally formed.

In the European education system, *science didactics* is now an established part of evaluation and research of teaching, where it relates the study of subject pedagogy to the study of the content taught (Wickman, 2014). In the following, I will describe the theoretical frameworks used in present study, as well as its relevancy and role in the out-of-school contexts such as the exhibitions of study.

## 1.5 Theoretical frameworks

I employ two overarching and interlinked theoretical frameworks in my investigation of exhibitions as designed environments for learning. The two frameworks are the theory of didactical situations (TDS) and the Anthropological Theory of Didactics (ATD), who both have their origins in the didactics of classroom-based mathematics in France. To be able to understand them in relation to the out-of-school contexts of present study, I therefore take departure in certain adaptations made by authors of similar studies (Mortensen, 2010, Achiam and Marandino, 2014 and 2016), allowing particular didactical tools to be applied to the specific field of exhibition design.

### 1.5.1 The theory of didactical situations (TDS)

The original theory of didactical situations (Brosseau, 1997) was developed on the basis of repeated experiments with carefully designed teaching-learning situations in mathematics classrooms. It was developed for the purpose of designing and/or analyzing mathematics education situations, but its flexibility has since been proven in a number of disciplines, including biology (Achiam, Sølberg & Evans, 2013) and pharmacology (Christiansen & Olsen, 2006), and in out-of-school contexts in addition to classrooms (Achiam, Lindow & Simony, forthcoming).

The theory of didactic situations describes the interaction between teacher and students in the so-called *didactical game*. This interaction takes form of a triangle consisting of the teacher, the student and the *didactical milieu* – which can be described as the situation in which the student can personalize the institutionalized knowledge, in order to relate it to the students already established reality (the *constructivist approach*).

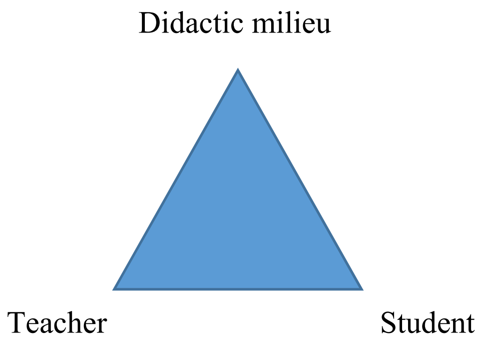


**Figure 1.1.** The relations of the didactical game

The transposition of institutional knowledge into personal knowledge of the student, can be seen as the counter-current of the personal knowledge (called *connaissance*) of the scientist, which he achieves when conducting science and 'discovering' something previously unknown. This new (personal) knowledge then needs to become institutionalized, before it can ultimately be recognized as public or common knowledge (now called *savoir*). Usually this institutionalization is done by publication in scientific journals, from where it might find its way into textbooks (in school), and from where teachers again need to *re-personalize* the same knowledge, in order to pass it on to the student via *didactical* and *a-didactical situations* (Winsløw, 2006).

Brosseau's *didactical situations* denote the active interaction between the teacher and the student within the *didactical milieu* (instruction, validation, etc.), and there are specific phases of this process within classroom teaching (see Winsløw, 2006). However, the student also works independently with the task(s) (the didactical milieu), without the teachers interfering – the so-called *a-didactical situations*.

### 1.5.2 Didactical situations in exhibitions

In contrary, most situations in exhibition dissemination will be *a-didactical* because the teacher is replaced by an exhibit element (object, text and/or hands-on activity). However, the exhibit design will usually have a specific learning goal either independently or in coherence with the theme and aim of the entire exhibition, and as such the exhibit elements represents *short a-didactical situations in pre-designed didactical milieus*.

The challenge of this de-personalized way of transposing knowledge could arguably be the (sometimes missing) link between the institutionalized knowledge, and the need of the visitor to *personalize* the knowledge in order to relate it to her own reality in the constructivist understanding. However, this very characteristic is also one of the primary qualities of exhibition dissemination, because of the informal and hence non-pretentious free-choice environment (Falk, 2001; Falk and Dierking, 2002). It is in this important (missing) link that we find the relevance of Chevallard's Anthropological Theory of Didactics (ATD), which constitutes a further development of the ideas of Brosseau – from whose work the theory of didactical transposition originates (Chevallard, 1991).

### 1.5.3 The Anthropological Theory of Didactics (ATD)

The *didactical transposition* uses that very link to follow the transposition of knowledge in four steps, as it changes from the institutional *scholarly* knowledge, to the *re-personalized* knowledge in the teacher (*knowledge to be taught*) and ultimately to the *personal* knowledge of the student in the didactical situation (*learned knowledge*). As explained by Bosch and Gascon (2006) it illustrates the necessary steps of changing – transposing – knowledge that was originally created in a scientific environment outside the education system, into knowledge suitable for teaching and learning inside the educational system, and thereby adapted to fit into educational situations of both didactical and a-didactical natures.

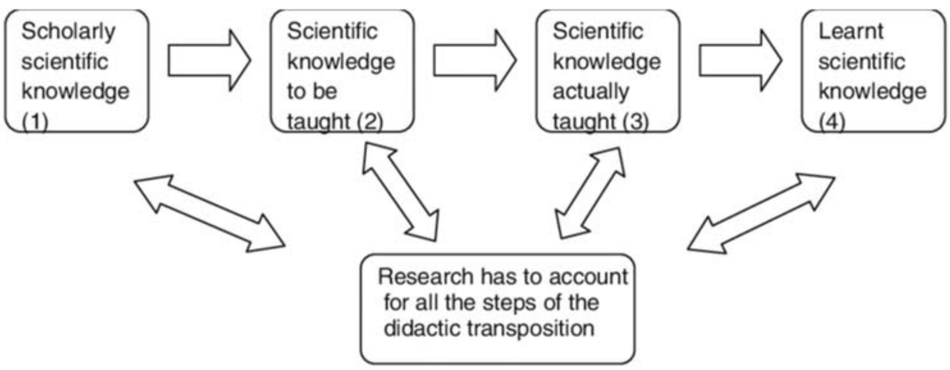


**Figure 1.2.** The four steps of the didactical transposition (after Bosch et al, 2006)

The most important consequence of this theory is that the minimal unity of analysis of any didactic situation cannot be limited to how the learner learns (see fig. 1.2.) but must consider the entire process of transposing the original scholarly knowledge into knowledge to be taught and further into taught knowledge (Chevallard, 1991; Bosch and Gascon, 2006).

These transpositional steps can then be utilized as both descriptive or analytical tools in the context of educational practice or design, and furthermore they might even have the potential to influence the design of educational content and programs, if the designers are sufficiently familiar with the theory while designing, as will be discussed in Chapter 5.

### 1.5.4 The Anthropological Theory of Didactics in exhibitions

Design-based out-of-school learning sites like exhibitions follow the same steps of transposition of knowledge as the formal education system, but since their *knowledge to be taught* does not come from textbooks, but rather from a physical exhibition environment, the transposition have been described to follow a slightly different trajectory. Simonneaux and Jacobi (1997), Gouvêa de Sousa et al (2002), and Mortensen (2010), represent three steps in the gradual modification of the didactical transposition into what they call the *museographic transposition* (fig. 1.3.). Mortensen (2010), modify the original steps of knowledge to be taught and taught knowledge into the so-called *curatorial brief* and the three-dimensional *exhibition milieu.*

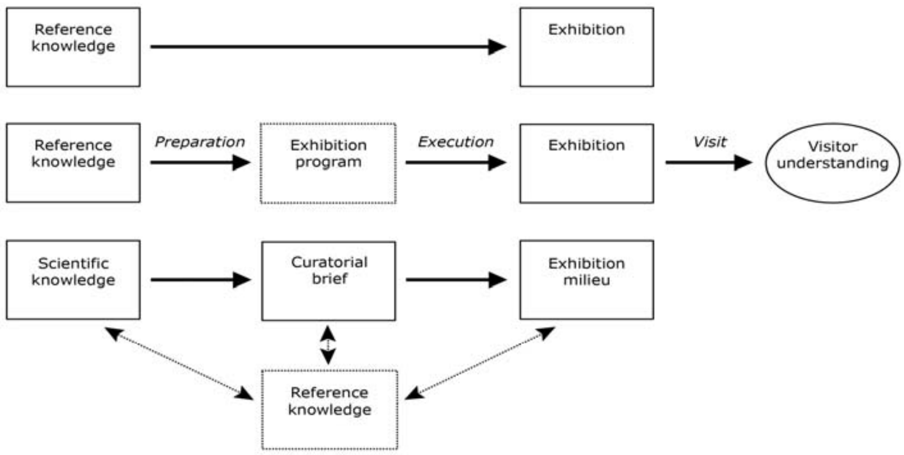


**Figure 1.3.** Evolution of the museographic transposition (figure reproduced from Mortensen, 2010). The uppermost example is after Simonneaux & Jacobi (1997), the second example is after Gouvêa de Sousa et al. (2002), and the final example is from Mortensen (2010).

The curatorial brief in the study of Mortensen (2010, see fig. 1.3.) represents the document often produced by exhibition designers containing the content these designers would like to implement and disseminate in their final exhibition products, and the outline of how they would like to do it. This document is usually derived from scientific knowledge in much the same manner as knowledge to be taught in school material is derived from the scholarly knowledge (fig. 1.3).

However, the curatorial brief is not always drawn from primary scientific publications alone, but quite commonly influenced by a popularization of the scientific knowledge derived from popular books, TV-shows, internet, etc. – what Clément (2006) calls KVP (knowledge, values and practice).

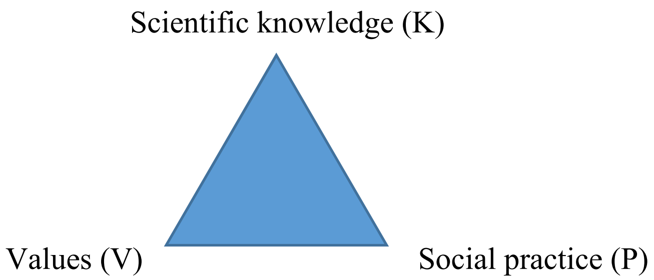


**Figure 1.4.** Clément's (2006) KVP model, the triangle representing conceptions (C)

In his KVP model (fig. 1.4.) Clément (2006) proposes that the conceptions (C) of not only the learner, but of teachers, researchers and everyone related to the learning process, are constructed in the interactions between these three poles of knowledge (K), values (V) and social practice (P), the latter alternatively understood as the disciplinary methodology of the disseminated content. Consequently, Clément does not distinguish between the concepts of *conceptions* and *misconceptions*, since these very concepts are at all times interchangeable and dependent of the factors influencing the triangle of KVP.

In the museum world, I find Clément's (2006) model to be of particular relevance, since the topics picked for dissemination in exhibitions, potentially could be subjected to economic interests (dependent on visitors actively choosing to buy tickets), rather than topics of scientific or societal relevance (see levels of co-determination next). Therefore, the disseminated topics potentially to a larger extend reflect 'what the public wants to learn', rather than 'what science really dictates', an important exception of course being the traditional museums that are still directly interconnected with their respective universities, and to a large extend reflect research and also priorities from their mother university.

An example of scientific knowledge being transposed radically in the development of an exhibition milieu, is the exhibit design described and analyzed by Mortensen (2011). She describes how a complex topic of cave beetle biology, for the sake of visitors, has been simplified to such an extent that the visitors actually fail to grasp the original scientific points during their interaction with the exhibit. To avoid such pitfalls Mortensen (2011), suggests that the notion of *praxeology* be used as an analytical framework as well as a potential design model when transposing knowledge in exhibition design processes (Mortensen, 2011; Achiam, 2013).

### 1.5.5 Praxeology

The notion of praxeology was developed as a component of Chevallard's Anthropological Theory of Didactics (Chevallard, 1999). It represents a general model of human activity and can as mentioned be used as an analytical tool as well as model of design-based learning environments (Achiam, 2013), in which case it usually encompasses a specific discipline and its methodologies. The term is comprised of the two Greek words praxos (practice) and logos ('the study of'), and it unites the concepts of task (T), technique (t), technology (θ) and theory (Θ).

The first two (task and technique) represent the practical practices of the discipline, and the latter two (technology and theory) represent the conceptual-theoretical component of that same discipline (Mortensen, 2011). The relation of the four components within the frame of praxeology (Chevallard, 1999) allows for investigation and study of the nature of specific disciplines, as well as the various tasks encompassed by them.

In the case of paleontology, a praxeological *task* could be the excavation of new fossil material, in which case the task is to physically find and excavate fossils from a certain time period. The *technique* is the method used to accomplish this task, as for instance to remove the upper layers of sediment to reach the older and deeper layers. The *technology* then is the rationale used by the paleontologist to justify his chosen technique, as for example the expectation of finding older fossils in deeper layers than younger fossils. The justification for this rationale is again found in the *theory*, in this case the principle of superposition (Steno, 1669) dictating that older layers of sediment, if not secondary distorted, will be positioned below younger layers as a consequence of the chronology of their sedimentation process.

### 1.5.6 Praxeology in exhibitions

As mentioned in the preceding, Mortensen (2011) suggests that the notion of praxeology be used as an analytical tool to compare the intended and the observed praxeologies of visitors interacting with an exhibit milieu. She subsequently suggests that it is additionally applied to the design process of exhibitions and their exhibit elements, to avoid potential pitfalls of distorting the original scientific content, preventing visitors to obtain the intended learning outcome, as was observed in the case of the cave beetle exhibit (Mortensen, 2013).

In the following, I will continue to look into the process of exhibition design, by following the theoretical framework of Chevallard even further, and present the factors of co-determination that he suggests as an even wider analytical tool. These levels have the potential to analyze a given design-based educational situation from the perspectives of every potential factor of influence – from the greater societal picture of society, to the internal constrains of as well the educational institution itself, as the individual learner at stake (Chevallard, 2002).

### 1.5.7 The hierarchy of levels of didactic co-determination

The didactical transposition that takes place during an educational design process is always under the influence of various different factors. The 'hierarchy of levels of didactic co-determination' was, as mentioned, developed as an analytical tool to identify and contextualize these factors of co-determination (Chevallard, 2002), and to place them in a hierarchy spanning from civilization and society and all the way down to the internal forces of the institutions and the disciplines themselves. The hierarchy has recently been adapted to the museum world (fig. 1.5) by Achiam and Marandino (2014 and forthcoming). In Chapter 3 I will elaborate further on the theoretical foundation of the hierarchy and use it in my analysis of the design process of the exhibition 'The First Dinosaur'.

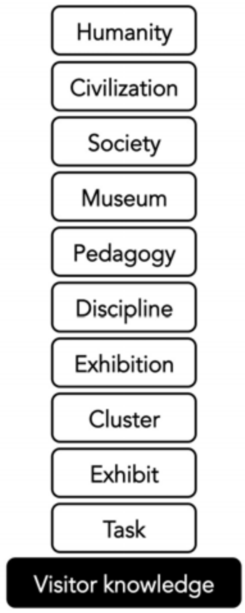


**Figure 1.5.** The hierarchy of levels of didactic co-determination as adapted to the museum context (After Achiam and Marandino, 2014)

In summary, despite their formal origins in the didactics of mathematics, the theoretical frameworks that comprise the theory of didactical situations and the Anthropological Theory of Didactics are increasingly being used outside mathematics and outside classrooms. These new contexts of application include the disciplines of biology and paleontology as well as the contexts of out-of-school education. Indeed, these are the contexts in which I will use the frameworks in the present work.

## 1.6 Methodology

My investigation of dinosaur exhibitions as platforms of science education in out-of-school learning contexts, and the design processes that produce these exhibitions has been conducted by means of various different methods of both quantitative and qualitative nature. The research is divided into five chapters, each addressing one or more of the three research questions and from one or more different angles.

**Chapter 2:** The second chapter conducts an *a priori* analysis of paleontology, to understand the epistemic qualities of the discipline, before conducting the empirical data collection of its practical use. Together with co-author Marianne Achiam, I investigate the first research question from an analytical point of view by means of a so-called *disciplinary matrix* (Kuhn, 1962).

> **RQ1:** In what way is natural history and the discipline of paleontology different from other branches of science in terms of disciplinary and educational qualities? How are such qualities relevant for exhibition dissemination, and how are they best implemented in the dissemination strategy?

Subsequently in Chapter 2, I explore the recent interest of dinosaurs in natural history museums and science centers by asking a number of select institutions about their prioritization of dinosaurs as well as 'science in the making' in their current exhibitions.

**Chapter 3:** In order to answer research questions 2 and 3 (in the following), I carried out an inquiry into the design of the exhibition 'The first dinosaur' on Geocenter Møns Klint.

> **RQ2:** Which factors affect the design process of exhibitions, and how can such a design process be optimized so that the integration of a specific disciplinary knowledge and the exhibit elements allow visitor outcomes to correspond to as well the disciplinary potential as the original designer goals? What kind of strategy can be applied to achieve such goals?

> **RQ3:** How does the ontological status of paleontological content matter (science in the making or ready-made science) influence the transposition of scholarly knowledge into content knowledge in an exhibition context, and how can this ontological status influence scientific literacy in visitors?

Semi-structured interviews were conducted with the four designers (myself excluded), and later transcribed. *Thematic analysis* (Braun and Clark, 2006) was applied to code the data, using the levels of co-determination, the museographic transposition as well as the ontogenetic status of 'science in the making' as focus.

**Chapter 4:** To provide more depth to the answer to research question 3, I conducted a visitor study to analyze the exhibition in its final stage, and its potential impact on scientific literacy in visitors. The visitor study was carried out as a *methodological triangulation*, using data of both qualitative and quantitative nature: Structured interviews, visitor observations and surveys. As for the interviews and surveys, they were conducted as a comparative analysis between the respective dinosaur exhibitions of Geocenter Møns Klint and Experimentarium.

**Chapter 5:** This chapter comprises of a case study of an exhibit element (the Excavation Table) and a summative analysis of the preceding findings. They were both carried out to inform the development of a tool to implement disciplinary content into exhibition design – in this case the discipline of paleontology (or more broadly, natural history). The analysis was carried out with a particular view to optimizing the role of the ontological status of paleontology as 'science in the making' (research questions 1, 2 and 3).

**Chapter 6:** The final section sums up the conclusions from each of the preceding chapters, and provides perspectivations for future research in the discussed research fields.

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# Chapter 2

# Paleontology as a discipline

## 2.1 Educational relevance

Paleontology is the study of ancient life. It is a branch of natural history that involves the study of extinct animals and plants, as well as the sediments surrounding their fossil remains. To investigate the educational qualities of paleontology as a discipline, I conducted an *a priori* analysis with Marianne Achiam as co-author. The analysis was used as the point of departure for understanding the role of paleontology within the field of natural history as well as its relevancy as a discipline in the educational system.

The analysis has been submitted for publication, and was finally accepted in January 2018, by the journal Nordina (Nordic Studies in Science Education). The first part of this chapter consists of the accepted manuscript: *The potential of paleontology for science education.* The analysis introduces the view that our current educational system represents a monolithic approach to science and scientific method and does not integrate the historical sciences (natural history) thoroughly into science education nor into contexts that promote public understanding of science (Frodeman, 1995; Benton, 2008; Wilcove and Eisner, 2000; Cleland, 2002, 2011).

In the second part of the chapter, I extend the discussion of the relevance of paleontology is to the out-of-school context of exhibitions, presenting the concepts of ‘science in the making’ and ‘pluralistic styles of reasoning’. Concluding the chapter is a small qualitative study on the decision-making behind choosing paleontology – in the form of dinosaurs – as exhibition content in a range of different institutions from traditional natural history museums to science centers, zoological gardens and safari parks. The study presents email interviews with the managing directors of seven different institutions, who all chose to display dinosaurs in their respective exhibitions in the form of either authentic fossils or animatronix dinosaur models.

## 2.2 The potential of paleontology for science education - The reintroduction of a historical science for improving scientific pluralism

**Abstract.** Science education frequently portrays science as a monolithic and experimental endeavour. Here, we argue that to counteract this simplistic conception of science, a reintroduction of the historically oriented sciences is in order. To this end, we analyse the discipline of palaeontology and its educational relevance. Using Kuhn's disciplinary matrix, we deconstruct palaeontology into elements for educational purposes, and subsequently examine how these elements can be utilised to enrich contemporary science curricula. We conclude by discussing how including palaeontology in science education encourages diversity, pluralism, and ultimately, public interest in science. **Accepted in the journal of NorDiNa (Nordic Studies in Science Education) with expected publication in 2019. Reprinted here with permission.**

### 2.2.1 Introduction

Present-day science education does not reflect the richness and pluralism of the scientific endeavour. Many primary and secondary school students encounter a version of science that is monolithic and mainly experimental. This simplistic view of science may discourage or even exclude children and youth from considering a science education trajectory; ultimately, it may even contribute to undermining public confidence in science. In the following, we describe and substantiate this problem in further detail with particular attention to the Nordic context. We then develop our proposal, namely that science curricula at the primary and secondary levels can be enriched through a renewed consideration of the so-called historical sciences, exemplified here by palaeontology. Our proposal is based on a deconstruction and reconstruction of palaeontology, and leads to concrete suggestions for activities in schools, teacher professional development, and in out-of-school environments. We conclude by discussing the implications of a reintroduction of palaeontology for increased inclusion in science education. The intended readership of this text includes not just science teachers, whom we hope will be inspired by the richness of palaeontology and the historical sciences, but also out-of-school science educators, teacher trainers and curriculum developers at the national level.

### ***The science in science education***

The natural sciences aim to understand the world through the accumulation of empirical evidence, acquired through observation and experimentation. Across the sciences, knowledge production is based on these two ways of gathering evidence; however, the relation(s) between observing and experimenting on one hand, and creating abstract, theoretical knowledge on the other, differ significantly both between and within the disciplines. This relation, the scientific method, can be divided into two general families: *Inductivism* and *hypothetico-deductivism* (Andersen & Hepburn, 2015). Inductivism reflects the view that observations and experiments precipitate the construction of hypotheses and theory; hypothetico-deductivism reflects the view that the theoretical hypothesis goes before the experiment or observation. Although neither family of methods can alone explain knowledge production in any scientific discipline (Forber & Griffith, 2011), many disciplines identify strongly with one account or the other. For instance, geology and palaeobiology make extensive use of the inductive method, because they deal with past events and/or events that cannot be replicated; thus, they are often termed *historical sciences*. Molecular biology and chemistry, for example, make extensive use of the hypothetico-deductive method because they deal with the controlled replication of events in laboratory settings; accordingly, these disciplines are often called *experimental sciences* (Cleland, 2002; Jeffares, 2008). However, the two approaches do not map directly onto the scientific disciplines; most disciplines use both experimental and historical methodologies (Forber & Griffith, 2011).

Yet, there is a tendency within science education to portray science as a step-by-step process of hypothesis testing that is fundamentally experimental (Bauer, 1992). For example, Blachowicz (2009) and Woodcock (2014) demonstrate how, in Anglo-American education resources, scientific method is often reduced to a sequence of steps that reflect the hypothetico-deductive method, e.g. forming hypotheses and testing them through experiments. Similar results have been found in education resources from Turkey (Irez, 2016), Brazil (Pagliarini & Silva, 2007), and China and Hong Kong (Cheng & Wong, 2014). Although some simplification is required for pedagogical purposes, representing scientific method in education as a universally applicable, mainly experimental, stepwise procedure seems both inadequate and misleading (Ault & Dodick, 2010; Woodcock, 2014).

### *The Nordic situation*

A similar issue may be at stake in the Nordic countries. At the upper secondary school level, national frame curricula in Finland, Norway, and Sweden reflect a view of chemistry as an experimental science that follows a series of steps including formulating a hypothesis and conducting an experiment (Vesterinen, Aksela, & Sundberg, 2009). Similarly, upper secondary school textbooks in Finland and Sweden portray chemistry as an exclusively experimental science, even though scientific claims in chemistry are also produced through other methods (Vesterinen, Aksela, & Lavonen, 2013).

In Denmark, no systematic studies have been carried out at the upper secondary level, but a quick glance in the influential textbook *Fundamentals of natural science - an introduction to scientific methodology* for upper secondary school shows the scientific method described as the formulation of a hypothesis and the subsequent experimental testing of it (Marker, Andersen, Pedersen, & Samsøe, 2012, p. 8). Other Danish textbooks have more nuanced formulations, i.e. *there is no one scientific method for the development of new theories; nor do scientists use only one method when they carry out scientific work* (Lund et al., 2010, authors' translation).

At the primary/lower secondary level, Johansson and Wickman (2012) demonstrate how the Swedish science curriculum has a more open view of scientific method, describing it as *the formulation of (simple) questions as well as plans for the systematic investigation of them* (p. 204; our translation). In contrast to this, the focus on problem-based education at the Danish primary/lower secondary level has led to increased use of Inquiry-Based Science Education (IBSE). In a position piece, Østergaard, Sillasen, Hagelskjær, and Bavnhøj (2010) argue the merits of the IBSE approach, sketching it in terms of the following four steps: definition of problem, construction of hypothesis; investigation; conclusion, validation, and contextualisation (p. 28, our translation).

While the positive results reported by these authors are laudable, the stepwise account of scientific method embodied by the IBSE method remains potentially problematic. Finally, Knain (2001) describes how Norwegian textbooks for the lower secondary level represent scientific method as *a three or four step procedure, which mimics hypothetical-deductive method* (p. 324).

Although this review gives a brief and somewhat sporadic overview of the situation, it does show that the scientific method is described as a stepwise, experimental, hypothesis-testing procedure in science education curricula and resources in the Nordic countries.

Because curricula and textbooks strongly influence teachers' practices (Binns, 2013), we assume that taught science in many cases has a similar, oversimplified representation of scientific method. This is problematic for several reasons. Learners may come to equate the practice of formulating and testing hypotheses in controlled laboratory settings with science as certain, precise, and predictive (Gray, 2014; Sharma & Anderson, 2009). This simplistic conception of science makes the uncertainties of scientific claims made by for example climatologists easy targets for those who wish to undermine them, ultimately weakening public confidence in science at large (Frodeman, 1995; Rudolph, 2007). Furthermore, the simplistic view of science as a dispassionate and depersonalised sequence of steps, rather than an authentic human adventure, may dehumanise science among learners and ultimately, in the public eye (McComas, 2008). But why does this skewed account of science exist?

### 2.2.2 Historical/experimental divergence

As mentioned in the preceding sections, the natural science disciplines exist on a spectrum from experimental to historical based on their different methodologies and epistemologies, which reflect different views of the world, of nature, and of science. In the following, we explore the reasons behind the divergence between the historical and experimental approaches.

***Cultural-historical reasons for the historical/experimental divergence***

Historically, the natural sciences have fluctuated between more theoretical approaches beginning with Aristotle in ancient Greece, and more empirical approaches, founded in the 17th century by Francis Bacon as a consequence of the many collected exotica appearing from the new world. Since then, the two approaches have alternated. Kant's and Newton's views on science and nature as purely objective unities in the 18th century were gradually subsumed by the perspectives of the 19th century natural philosophers Dilthey and Windelband, who viewed science as having more subjective elements, represented by the knowledge, values and even emotions of the executive scientist (Baron, 2004). The pendulum swung back towards logical positivism in the 20th century when Karl Popper introduced the philosophical tool of empirical falsification, ultimately supporting the view of science as having only one universal method. And in the mid 20th century, science philosopher Thomas Kuhn (1922-1996) established the term paradigm as a concept to explain the shared views and values of a given scientific environment, ubiquitously influencing the work of the researchers, and allowing only rare scientific revolutions – paradigm shifts – to mentally open up the world of science to new ways of thinking. On the backdrop of these fluctuating currents, we can see the present-day focus on nanotechnology and the industrial use of scientific results as a return to the more theoretical analytic philosophy of what today is widely considered as the one and only scientific method: The experimental approach (Baron, 2004; Cleland, 2002).

***Epistemological reasons for the historical/experimental divergence***

In addition to the cultural-historical explanation described in the preceding section, the divergence between historical and experimental approaches to science is caused by their two distinct ways of constructing hypotheses and validating evidence (Cleland, 2011; Gray, 2014). The experimental method sets up controlled laboratory settings and predicts the outcome. Consequently, the experiment can be repeated a number of times in an attempt to avoid false positives or false negatives, which gives the results an appearance of falsification. However, this appearance is deceptive, since true falsification, or proof of validation, can never be obtained for certain. No matter how many times one repeats the experiment, it will always be subject to effects from the environment or chance (Cleland, 2002).

In contrast, the historical method takes a point of departure in several hypotheses, of which one is potentially more likely than the others. The quest for this one hypothesis in the traces of the past events can be compared to a criminal investigation, with the advantage of what Cleland (2001, 2011) calls *the time asymmetry of causation.* This is the phenomena of an event leaving a multitude of traces of its existence after the event, but none before the event. This gives the historical scientist an explanatory advantage (depending on the state of preservation and the number of traces left and found), compared to the experimental scientist trying to predict the future – which is of course impossible. It is obviously not possible, either, to gain certain knowledge of what happened in the past. One can only know what is most likely to have happened in the past, in terms of parsimony. This comparison at least leaves both the historically and the experimentally oriented sciences without definite ways to prove their results, but with very different methods to attempt to do so (Cleland, 2001, 2002, 2011).

In summary, the exploration of the divergence of historically and experimentally oriented sciences points to the following conclusion: Although the historically oriented sciences seem to be at a disadvantage in contemporary society in terms of perceived relevance and validity, there is no reason to exclude the historical approach from our discussions of science. On the contrary, the historical sciences have an important role to play in creating a more realistic and complete version of science and scientific method among learners (King & Achiam, 2017). In the following, we substantiate this argument employing the discipline of palaeontology, but we believe our thesis could be supported by any of the historically oriented sciences. Furthermore, we discuss the implications of a stronger presence of palaeontology in science education, both inside and outside school. Throughout this text, we address science education at the primary and secondary school level, but we believe this problem goes beyond the school system and into the larger public.

### 2.2.3 The discipline of palaeontology

Palaeontology is the scientific study of prehistoric life through investigations of its fossilized traces, located between the study of life (biology) and the study of the sedimentary rocks wherein the fossils are embedded (geology). It originated in ancient times and emerged in Europe in the 1600s as a part of natural philosophy. An important milestone was Steno's thought that Earth is not an unchangeable unit, but contains geological layers representing different time eras, with the oldest layers at the bottom and potentially containing fossilized life from the represented era. The consciousness of geological deep time and life following a succession of layers, along with Cuvier's foundation of comparative anatomy in the late 1700s, paved the way for Darwin's controversial publication *On the Origin of Species* in 1859. Palaeontology subsequently became an independent discipline in the late 1800s. In the following, we analyse the discipline of palaeontology to elucidate its educational significance.

#### *Educational significance*

The term educational significance is part of the Model of Educational Reconstruction (MER) designed to scrutinise areas of science to gauge the merit of including them in teaching and dissemination (Duit, Gropengiesser, & Kattmann, 2005). It has been used in a number of different disciplines, e.g. nanoscience, where Laherto (2010) used MER to evaluate the utility of incorporating nanoscience and technology into curricula, or cell biology, where Riemeier and Gropengießer (2008) used it to clarify the subject of cell division for the design of teaching/learning sequences. It has three main components: 1) Clarification and analysis of science content, 2) Research on teaching and learning, and 3) Design and evaluation of teaching and learning sequences. Here, we employ the first component, clarifying paleontological content in order to elucidate its educational significance.

We approach the discipline of palaeontology using Kuhn's notion of a disciplinary matrix, consisting of the *symbolic generalisations*, *metaphysical presumptions*, *values*, and *exemplars* shared by its community of practitioners (Kuhn, 1962). A discipline's symbolic generalisations are those formalisations that are not usually questioned by scientists within the discipline (Kuhn, 1962); they correspond to its central theories or laws. A discipline's metaphysical presumptions are the epistemic and ontological beliefs held by its practitioners. A discipline's values refer to the criteria used to judge the explanatory sufficiency of evidence, whereas its exemplars are the characteristic problems and objects that give the discipline empirical substance (Kuhn, 1962). These four elements structure our analysis and subsequent suggestions about educationally important aspects of palaeontology.

***Theory in palaeontology***

The most important symbolic generalisation of palaeontology is the theory of evolution by natural selection. The theory of evolution is not an empirically testable generalisation in the sense of the universal laws of physics or chemistry. The theory leads to how-possibly questions rather than why-necessarily questions because it involves directional, asymmetric, and temporal relations between species (Cat, 2014). For example, the theory can retrodictively explain how birds and crocodiles can most possibly be the descendants of an extinct animal called an archosaur, but it cannot explain why birds and crocodiles are necessarily the descendants of archosaurs, because it cannot predict the exact course of evolution. This characteristic causes the theory of evolution to conflict with a widespread perception of what a scientific theory is, namely something that can make predictions (Dagher & Boujaoude, 2005). This perception is a misunderstanding: In fact, both concepts of prediction and retrodiction are equally important across a range of sciences (Gray, 2014).

### *Educational significance of theory in palaeontology*

From an educational point of view, a more sophisticated understanding of the theory of evolution among learners may precipitate more nuanced and realistic views of the nature of scientific theory across the disciplines. Studies suggest that the most efficacious way of disseminating the theory of evolution is to engage learners in inductive reasoning patterns that mirror those of palaeontologists, rather than taking the theory as a starting point and attempting to infuse it into content (cf. Dagher, Brickhouse, Shipman, & Letts, 2004; Passmore & Stewart, 2002). This way of grounding science education in specific cases would help learners grasp what science is about in each particular instance (Rudolph, 2000), allowing them to understand that different lines of scientific inquiry are associated with different theory structures (Dagher & Boujaoude, 2005).

### *Epistemic and ontological beliefs in palaeontology*

Coherence is a central belief in palaeontology, i.e. the dependency between contemporary forms and past events, but also between past events (Currie, 2017). Palaeontologists draw on this belief when dealing with the challenge of interpreting long-past events. One example is the technique of comparative anatomy which involves comparing the anatomy of different species, both extinct and extant, to postulate a common cause for them (von Bonin, 1946). Similarities may indicate shared ancestry (e.g. the shared bone structure of whale and human front appendages), or they may indicate convergent evolution (e.g. wings in bats and birds). In either case, palaeontologists exploit the dependency relationship between past entities and events: A shared ancestor and the constraints of this ancestry on the genotype and phenotype of descendants, and similar (past) selection pressure, respectively.

### *Educational significance of epistemic and ontological beliefs in palaeontology*

Studies show that engaging learners in the intellectual problems of palaeontology can help them develop its techniques of inquiry for themselves; developing these techniques, in turn, allows the discipline's epistemic and ontological assumptions to emerge. For example, Thomson and Beall (2008) show how learners used comparisons of skulls to make inferences about diet and locomotion among hominids, which in turn led them to construct possible phylogenetic pathways for hominid evolution. Elsewhere, Achiam, Simony and Lindow (2016) show how groups of learners engaged in comparing the anatomical features of modern birds and a fossil *Archaeopteryx* (a small feathered dinosaur) identified a number of similarities and correctly identified them as being due to shared ancestry or convergent evolution, respectively.

The significance of letting learners develop disciplinary techniques and concepts for themselves, in content-rich contexts, is that it counteracts the notion of science as a depersonalised, monolithic practice, devoid of personal or social features. It emphasises the point that science involves the use of the imagination to engineer methods of inquiry that are suitable within specific contexts (Ault & Dodick, 2010).

### *Values in palaeontology*

What is considered appropriate evidence in palaeontology differs from what is considered appropriate in the experimentally oriented sciences (Passmore & Stewart, 2002). These different patterns of evidential reasoning utilise different sides of the time asymmetry of causation mentioned previously. Palaeontologists are typically not able to directly test their hypotheses by means of controlled experiments (Cleland, 2002). Instead, palaeontology often deals with indirect and circumstantial evidence such as fossil traces or homological structures in different species, and the quality of effective palaeontological research is often based on how well the hypothesis explains a variety of such evidence. For example, the hypothesis of an asteroid hitting Earth 65 million years ago can explain a variety of historical evidence such as the thin layer of iridium-containing sediment that can be found throughout the world, the presence of a large crater in the Gulf of Mexico, and the mass extinction of animal and plant species evidenced by the fossil record. In other words, effective *explanation* is valued in palaeontology (Cleland, 2011).

### *Educational significance of values in palaeontology*

Explanatory reasoning of the kind used in palaeontology requires combining many items and types of evidence, both for and against the hypothesis in question; this again necessitates understanding scientific concepts in addition to those familiar to the experimentally oriented sciences (e.g. predictions, controls, and variables). Multiple working hypotheses, retrodiction, abductive reasoning, and reasoning from analogy are some such concepts (Dodick, Argamon, & Chase, 2009); in fact, it is argued that not only are these concepts important resources for understanding palaeontology, they are also important resources for creating a more nuanced understanding of the experimentally oriented sciences as well (Gray, 2014).

### ***Exemplars in palaeontology***

Exemplars are what give theory empirical content (Kuhn, 1962), and serve as a kind of practical approach to the discipline. In science education, exemplars may be thought of as the textbook or laboratory examples that learners engage with, and that are used as introduction to the discipline's tacit knowledge. In palaeontology, these exemplars are fossils. Fossils are rare, and have unique fossilisation histories, which affect what can reliably be predicted from them (Ault & Dodick, 2010), unlike the natural kinds of chemistry or physics, i.e. compounds or particles (Frodeman, 1995).

Of special note are transitional fossils, so called because they display anatomical features that are shared by several groups of species, thereby indicating a genealogical relationship between those groups. Perhaps the most well known transitional fossil of them all is the aforementioned *Archaeopteryx*, which represents a transitional form between reptiles and birds. It thus represents a classic exemplar of a hypothesis (speciation as the basis of evolution) embodied by a concrete object. *Archaeopteryx* has a long bony tail and teeth (as do reptiles), but also asymmetrical feathers suited for flight (as do only birds). When the first specimen was discovered in the 19$^{th}$ century, transitional forms were unknown, but this concept has since proved crucial in the understanding of evolutionary mechanisms and speciation processes.

### ***Educational significance of exemplars in palaeontology***

Transitional fossils may have an important role to play in education. Transitional fossils are often termed *missing links*, which is a concept that can easily be misleading (Miller, 2012). A transitional fossil does not represent a link in a chain that proceeds directly from simple to complex, because evolution does not take place in a linear sequence (Mead, 2009). Rather, evolution should be conceptualised as a branching structure, where transitional fossils represent descendants of shared ancestors. For example, the transitional fossil *Archaeopteryx* is descended from the same ancestor as modern birds and reptiles; thus, *Archaeopteryx* shares features with both of those groups but cannot be said to be an intermediate between them (cf. Mead, 2009). If used carefully in education, transitional fossils may thus enhance learners' understanding of the process of speciation, giving rise to a more sophisticated understanding of the evolutionary process.

Additionally, research points to the educational efficacy of scientific objects. Tangible scientific objects have been shown to increase learners' motivation (Cook et al. 2014), suggest lines of inquiry (Kreuzer & Dreesmann, 2016), and make scientific processes visible (Roehl, 2012). Accordingly, the macroscopic fossils of palaeontology with their often strong visual cues seem especially well suited for educational purposes.

### 2.2.4 Palaeontology in education

On the basis of the analysis of its educational relevance, palaeontology has a number of features that make it germane to richer and more inclusive approaches to science education. Not only can an increased attention to palaeontology provide learners with a more complete picture of the natural sciences, but it can also improve and nuance their understanding of the experimentally oriented sciences. Accordingly, in the following we offer concrete suggestions for systematically enriching learners' experiences with science in their education processes, both in schools and outside them.

***Science classrooms***

As discussed in the opening sections of this text, the perspective on science in many Nordic education contexts may lead learners to equate scientific practice with the production of facts through the linear formulation and testing of hypotheses. Based on our analysis, we suggest that palaeontology offers the means to go beyond what Sharma and Anderson (2009) critique as the rule-bound science experiments that consistently provide predetermined answers.

We suggest that the introduction of palaeontological inquiry activities, with their tangible objects and prompting of contextually relevant techniques, can provide learners with complex science milieus. In such milieus, learners have opportunities to engineer their own lines of inquiry on the basis of the macroscopic and often compelling fossil objects; this, we argue, prompts the learners to use their empirical constructs as rhetorical tools to convince themselves and others of their claims (Achiam, Lindow, & Simony, forthcoming). When learners create and justify knowledge claims using retrodiction, abduction, reasoning from analogy and multiple working hypotheses, not only do they gain domain-specific insights into palaeontological methodology, they may also gain an improved understanding of inquiry in the experimentally oriented sciences (Gray, 2014).

Although the tangible and macroscopic nature of many palaeontological objects means that there are many ways to conduct authentic, hands-on activities without expensive equipment or laboratory apparatus (King & Achiam, 2017), a potential obstacle to implementing palaeontological inquiry in the classroom is that schools do not always have access to specimens and objects. Even though casts and models can be relatively cheaply obtained, we acknowledge that school budgets are restrictive. However, with careful planning, the educational affordances of palaeontological objects may be made available through other types of media, i.e. digital representations such as *The Human Animal* (The Natural History Museum of Denmark, 2013), images, or even simple hand-outs (e.g. Achiam, Sølberg, & Evans, 2013). These representations can arguably embody the salient features that prompt authentic palaeontological inquiry.

***Teacher professional development***

Incorporating palaeontology in science education would be impossible without the science teachers. Research shows that science teaching practices are strongly affected by textbooks (Binns, 2013); given the emphasis in science textbooks on the experimental approach, we might assume that science teachers as a general rule do not teach historical approaches in their science classes. Furthermore, studies show that pre-service teachers rarely encounter the distinctions between experimental and historical approaches in their training (Dodick et al., 2009; Gray, 2014). Although we acknowledge that the studies cited here describe the conditions in the USA, we assume that science teachers in other countries face similar situations: Implementing palaeontological activities in science education represents a challenge to many science teachers.

One study analysed science teachers' construction of scientific arguments in the classroom for topics that involved experimental and historical approaches, respectively (Gray & Kang, 2014). These authors found that the arguments made by teachers did indeed reflect differences between the approaches. While in the experimental teaching units, the teachers portrayed the epistemic process of science as a linear progression from data to knowledge claim; in the historical science units, the process of science was portrayed as the accumulation of multiple pieces of data, leading towards a generalised claim (Gray & Kang, 2014). This means that even without specific training in the diversity of scientific methods, teachers may to some extent be capable of giving pluralistic accounts of the natural sciences. In our analysis of the educational significance of palaeontology, we pointed to the significance of explanatory reasoning. Palaeontology, like other historically oriented sciences, involves constructing and evaluating arguments for and against multiple hypotheses based on the evidence. Even though incorporating palaeontology inquiry activities in science lessons may be a daunting prospect for teachers with no training in the historically oriented sciences, we argue that to the extent that science teachers spontaneously invoke patterns of argumentation that are particular to the historical sciences in their teaching sequences (as demonstrated by Gray & Kang, 2014), they are already en route to offering their students a more pluralistic understanding of science. Starting small and gaining confidence could be the key for teachers, using the many resources freely available online, e.g. *Teaching Paleontology in the 21$^{st}$ Century* (Teach the Earth, n.d.).

***Science education in out-of-school settings***

More and more, the science education community focuses on the special contributions made to science education by museums, science centres, and other out-of-school learning institutions. Indeed, if teachers feel overwhelmed by the thought of introducing palaeontology in their classrooms, out-of-school science education institutions are well-positioned to engage learners in activities related to the historically oriented sciences and specifically, palaeontology. One familiar way to encounter palaeontology is in natural history museums, which frequently display authentic paleontological objects such as dinosaur skeletons and ichnofossils to the enthusiasm of their visitors. Other types of institutions may display other kinds of engaging palaeontological objects, i.e. animatronic dinosaurs, simulated fossil digs (physical or digital), or footage of real fossil excavations, and some may even offer programs where participants can participate in real palaeontological excavations. Common to these representations of palaeontological objects and practices is that they offer glimpses into the real workings of paleontology by providing compelling narratives about the often exotic expeditions that presaged them, the so-called Bone Wars, ancient worlds, and the intriguing process of palaeontological knowledge production (see e.g. Estrup, 2017).

Research shows that disseminating science through such historical narratives has a positive effect on the understanding, retention and interest of learners (McComas, 2008). Specifically, the dissemination of difficult concepts such as the theory of evolution has been shown to be especially effective when it is embodied in its historical context. For example, Miller (2012) exemplifies how narratives of on-going fossil discoveries can be used to illustrate how different evolutionary hypotheses have been supported through time. Such narratives can help learners understand the interplay of retrodiction and prediction, not only in palaeontology, but across a range of sciences. Furthermore, disseminating palaeontology in its historical context provides learners with a more human and complete picture of the scientific enterprise (Miller, 2012), making it inclusive to a wider variety of learners.

Finally, excursions outside the classroom have been shown to enhance learners' motivation when used as a supplement to classroom-based teaching (Braund & Reiss, 2006). Accordingly, we encourage natural history museums, science centres and other out-of-school science institutions to develop their educational strategies towards clear distinctions between the historically and experimentally oriented sciences. Not only will this distinction benefit learners on school excursions, but also the members of the public who visit to conduct their own, voluntary science explorations.

### 2.2.5 Conclusion

Contemporary society is based on scientific knowledge, innovation and democracy; qualities that require comprehensive education in the natural sciences. Hence, it is alarming that science education portrays science as monolithic and univocal, recognising only the experimentally oriented sciences. In this text, we have argued how a reintroduction of the historically oriented sciences in the education system could reverse this tendency. In our analysis of the educational relevance of palaeontology - of one of the most classical of the historically oriented sciences - we have shown how palaeontology and its theory, values, epistemic and ontological assumptions, and exemplars have significant potential for a more complete, humanised, and pluralistic conception of the natural sciences. We suggest this will provide children and youth with more diverse pathways into science, thereby increasing the diversity of science learners and providing the basis not only for increased recruitment into scientific career pathways, but also for more well-informed democratic citizenship.

## 2.3 The potential of paleontology in exhibitions

In section 2.2, it was concluded that paleontology contains certain features that make it suitable for re-introducing natural history to science education, both in classrooms and in more informal arenas of dissemination. In this part of the chapter, I will use the conclusions from the paper to target the informal arenas, focusing especially on exhibition dissemination, and arguing that paleontology – also in museum contexts – can be used to enhance a more pluralistic approach to science. Finally, I will investigate if there is a link between these arguments and the decision-making concerning dinosaurs as exhibition topics, in a range of different institutions.

In the analysis of the manuscript, the four elements of educational significance (theory, epistemic beliefs, values and exemplars) all pointed to the common quality of paleontology encouraging active engagement in the learner. This engagement being either in the form of applying authentic *scientific inquiry* to the teaching situation and/or potentially involving the use of *authentic objects* (see pages 33-37). Presenting such authentic scientific inquiry to the visitors of a museum exhibition is one of the potential approaches to the strategy of 'science in the making' as the ontological status of exhibition design. In my first line of argumentation for using paleontology to enhance pluralistic science in informal arenas, I will introduce 'science in the making' as a concept.

### 2.3.1 Science in the making (versus ready-made science)

Latour (1987) originally described scientific enterprise as a two-faced Janus, with one face representing 'ready-made science' and the other representing 'science in the making'. The two faces speak, according to Latour, with each their voice, representing different mindsets regarding the nature of science being either universal and univocal (ready-made science) or a constant process of fusing new facts into established knowledge (science in the making).

Shapin (1992) subsequently argues that the public ought to understand 'science in the making', because an alienation towards scientific practice has taking place since the disjunction of residences and workplace. He mentions that the researcher practically lived in his laboratory a few centuries back, in much the same way as the miller lived at the mill. A few years later Arnold (1996) follows Shapin's line of reasoning to the museum world. He argues that the first museums practically housed the laboratories of research, but that modern museums have been separated from their research institutions professionally as well as geographically. He also describes how more and more museums are now again attempting to regain the relationship to research by presenting scientific process in addition to its products (Arnold, 1996). Toon (2005), on the other hand, still designates science centers as 'black boxes', referring to scientific practice being 'taken for granted', neglected and the buildings themselves as being considered architectural 'public monuments', rather than presenters of valuable scientific enterprise (Toon, 2005). Hine and Medvecky (2015) likewise criticize museums for remaining ignorant towards 'critical science' and denying to display 'unfinished science' – or science still in the making.

***Science in the making in dinosaur exhibitions***

In the case of dinosaur exhibitions, only the products have traditionally been displayed – fossils, skeletons and footprints, etc. – but recent years have also seen an increased use of scientific process in the dissemination of paleontology, as illustrated by the number of institutions in the next section deciding to disseminate the dinosaur excavations as well as the fossil products (section 2.3.4.). One reason could be the before mentioned disciplinary features of paleontology we extracted from Kuhn's matrix in the *a priori* analysis, and the fact that the inquiry of paleontology is relatively concrete compared to the more abstract use of models and calculations (Cleland, 2002; Gray, 2014). A number of examples already exist of the use of paleontological inquiry in teaching situations (Einarsson, 2018; Achiam, Simony and Lindow, 2016; Miller, 2012; Ault and Dodick, 2010; Thomson and Beall, 2008).

In paleontology scientists dig out bones, compare ancient life with modern life (comparative anatomy), and evaluate traces of the past to retrodict ancient scenarios (by means of multi-hypothesis methodology), etc. All of these steps are relatively easy to follow for non-scientists, and therefore suitable for presenting *authentic scientific inquiry*, which according to Crawford (2014), is a variation of inquiry teaching that aligns closely with how scientific enterprise is executed in practice. Such inquiry-based teaching therefore invites the learner inside the procedural enterprise of the discipline and has the potential to combine the products of science – or ready-made science (facts or content-knowledge) with the procedural knowledge of science – or 'science in the making' (Arnold, 1996; Ault and Dodick, 2010, Trna and Trnova, 2012).

In paleontology, the arguments of process-oriented dissemination can additionally count the countercurrent of dissociation and alienation of the scientific products (e.g. factual knowledge, inventions, fossil findings and discoveries) from the process in which they are derived (Shapin, 1992, Trna and Trnova, 2012). The advantage of such practical linkage can be found in the nature of the human brain who remembers and understands more efficiently if subjected to a social or a historical context (Norris et al, 2005; McComas, 2008). However Ault and Dodick (2010) argue that for this meaningful linkage to happen, the scientific process also needs to be attached to a certain narrative, without which the meaning will fail to occur. They state that 'Although the study of scientific processes may prompt active learning, processes do not constitute story; they fail to achieve the narrative that brings meaning to experience' (Bruner 2002; Ault and Dodick, 2010). Avraamodou and Osborne (2009) make the same claim about science dissemination in general, and state that such narratives are important for making science meaningful, relevant and accessible. The example of Ault and Dodick (2010) is using dinosaur footprints in the representation of paleontological reasoning. As an example, they use the analogy between biped theropod dinosaurs and birds (example of shared ancestry), and quadruped sauropods and hippos as an example of convergent evolution. However, they argue that a satisfactory narrative has to be linked to the methodological orientation, or else '…the enduring adherence to a process approach obscures how conceptualization intertwines with methodology' (Ault and Dodick, 2010). As stated in an earlier publication: 'Paleontological inquiry, representative of the importance of context to observing and inferring in particular ways, promises fascinating stories that amplify experience with meaning' (Ault and Ault, 2009).

An important epistemic quality of displaying scientific process – or 'science in the making' in dinosaur exhibitions, is the visitors' potential to increase their understanding of the nature of knowledge itself. This can be illustrated by the fourth dictum of Janus (Latour, 1987): 'When things are true, they hold' (ready-made science) or 'when things hold, they start becoming true' (science in the making). This not only goes for producing a true model (like the DNA helix exemplified by Latour in his original paper), but also for deducting a true hypothesis of for instance what happened in the ancient past by means of multiple hypotheses (Cleland, 2002). For using multi-hypothesis methodology in the first place, however, we need to challenge the established 'styles' of reasoning within scientific enterprise and public understanding of this, which now tends to be rather monolithic towards experimental reasoning, as was argued in our *a* *priori* analysis of paleontology. For this purpose, I will now introduce the concept of 'pluralistic styles of reasoning' as conceptualized by Kind and Osborne (2015).

### 2.3.2 Pluralistic 'styles of reasoning'

As discussed in the a priori analysis in the paper (section 2.2.), the unique qualities of paleontology to a large extent correspond to the unique qualities of natural history in general, and the analysis provided some good arguments for reintroducing natural history to the argued univocal methodology presented in modern science education and dissemination today. However, as also stated in the paper, a current monolithic approach to science and methodology exists, which is not supporting those historical qualities or their mode of reasoning. A view that was recently supported by King and Achiam, 2017.

Kind and Osborne (2017) describe as many as six different 'styles of reasoning', of which they argue that the established 'scientific method' uses only two: 'Experimental evaluation' and 'Hypothetical modeling' (Kind and Osborne, 2017), corresponding roughly to the methodology of experimental science, as also stated in our a priori analysis. Of the remaining four styles of reasoning, I would argue that three of them fit into the methodology of natural history: 'Categorization and classification' (the original natural history of describing nature), 'Probabilistic reasoning' (use of statistics and parsimony) and 'Historical-based evolutionary reasoning' (multi-hypothetical methodology).

Hacking (2012) already traced the origin of these styles of reasoning in his paper 'Language, Truth and Reason' 30 years later', and he describes the different 'styles' much in the same manner as Latour describes the face of 'science in the making' in the fourth dictum of Janus:

> These forms of reasoning exist because they have been, and still are, successful in answering the ontological, causal, and epistemic questions that are the focus of the sciences. They are good not because they detect the truth; rather, they are good because they are successful. And, because of their success, 'they have become part of our standards for what it is to find out the truth' (Hacking, 2012, p. 605).

As it is important to understand scientific process and inquiry, and include it into science education, it is correspondingly important to include the various 'styles' of reasoning whether they be of experimental, historical or mathematical nature (Kind and Osborne, 2017; Hacking, 2012).

In the following empirical analyses, I will investigate how the unique ‘paleontological’ styles of reasoning, can be used to support the dissemination of paleontology as a discipline in exhibition contexts. First, however, I have asked decision makers what made them choose paleontology as their topic of dissemination in the first place.

### 2.3.3 Paleontology as an educational exhibition topic

As a consequence of the monolithic approach to science it is now, as mentioned in the preceding, more up to out-of-school learning sites, like natural history museums and science centers, to play a significant role in the dissemination of the historical methodologies and styles of reasonings (Rennie and Williams, 2002; Kemp, 2015; King and Achiam, 2017).

In the following, I introduce and present a small study on the relationship between some of these learning sites on the one hand, and paleontology as process and product on the other, based on e-mail interviews with the managing directors of seven different institutions, each being representatives of the out-of-school science education.

#### ***Out-of-school education institutions***

Natural history museums obviously constitute natural platforms for disseminating natural history, as has been their traditional ontological purpose (Wilcove and Eisner, 2000; Benton, 2008; Carnall *et al.*, 2013, Rieppel, 2012). However, Benton laments the decline of the natural history museum in correspondence to the decline of natural history itself. He states that: ‘[P]rogrammed “fun” is not necessarily pleasure, nor is entertainment the only means of sparking an interest in science. The people who run museums these days seem to think that children cannot enjoy quiet reflection’ (p. 176). He thereby illustrates the later point of Carnall *et al.* (2013), that the public from nostalgic reasons wants natural history museums to stay as traditional as possible (how they remember them when *they* were kids), leaving few possibilities for museum staff and designers to re-think and develop the dissemination of natural history museums (Carnall *et al*., 2013).

However, a new actor has in modern time, entered the stage of science dissemination to the public: The science centers! They are, unlike the museums, usually devoid of collections and objects, and aim to disseminate the principles of science, rather than its discoveries and accomplishments (Ogawa *et al*., 2009). Their educational strategies follow the so-called *discovery pedagogy*, where the visitor through hands-on activities and interactive exhibitions is encouraged to discover the 'principles' behind science individually or in groups (Oppenheimer, 1968). Science centers have nonetheless been criticized for not raising questions about scientific methodology (Toon, 2005; Hine and Medvecky, 2015), and the process behind the creation of scientific knowledge (science in the making), thus provoking the same kind of criticism as has been directed towards their museum relatives (Wilcove and Eisner, 2000; Benton, 2008).

### 2.3.4 Reasoning behind choosing paleontology as exhibition content

As presented in preceding sections, the discipline of paleontology holds a unique potential for addressing 'science in the making' for educational purposes. Since I additionally experienced an increased interest in my personal network, towards acquiring and exhibiting dinosaurs in various forms (in the form of authentic skeletons or the form of animatronix models), I decided to investigate some of the reasoning behind this apparent new tendency.

My first observation was that the tendency was not limited to natural history museums and science centers (constituting my personal network), but also included zoological gardens and safari parks, of which some were requesting my help as an external consultant in the process (e.g. Aalborg Zoo). Second, I observed that many of these institutions besides disseminating the dinosaurs (products of paleontology), also prioritized to disseminate the expeditions and excavations unearthing these dinosaurs, and thereby following the exhibition strategy of 'science in the making', not only presenting science as products, but also as processes (Arnold, 1996).

This growing interest in the products and processes of paleontology across institutions prompted me to address this issue as well, in the small e-mail-based study of science education that I was conducting on institutions having recently incorporated dinosaur exhibitions into their dissemination activities. The study consisted of e-mail interviews with seven managing directors of seven Danish and international institutions who all followed this trend, and who represented as well the traditional disseminators of paleontology (natural history museums and science centers) as the newcomers with living animals as their core subject of dissemination (zoological gardens and safari parks).

***Methodology***

Interview questions were sent by email to seven managing directors of seven different institutions (see Table 2.1.). In qualitative interviews, there are some obvious disadvantages to the written format compared to the spoken, like asynchronous interaction in time and the lack of trust, confidentiality and contextual richness of face-to-face interaction (Brinkmann, 2014). Nonetheless, the method was in this case considered satisfactory, since the topic was not related to any personal or emotional content, and the questions were addressing people who, qua their professional positions, are used to express themselves proficiently in writing. I later employed a thematic analysis (Braun and Clark, 2006) to analyze the e-mail data, using the institutional background as well as the ontological status of 'science in the making' as focus.

**Table 2.1.** Respondents to the e-mail questions

| Name | Institution | Dinosaur acquisition |
|---|---|---|
| Morten Meldgaard | Natural History Museum of Denmark (SNM) | Bought an almost complete *Diplodocus* skeleton, Misty, from Wyoming on an auction in 2013. |
| Johannes Vogel and Linda Galle | Museum für Naturkunde, Berlin | Received the exclusive rights of study and display of the privately owned black *T. rex*, Tristan Otto, who was unearthed in Montana in 2012. |
| Edwyn van Huis | Naturalis in Leiden | Joined a dinosaur excavation in Montana, buying the ownership of the unearthed skeleton of Trix – the *T. rex*, as well as the rights to display her and the excavation process. |
| Asger Høeg | Experimentarium in Copenhagen | Presented a dinosaur exhibition (with as well authentic fossils as animatronix dinosaurs) in 1997, as one of the very first science centers. |
| Nils Natorp | Geocenter Møns Klint (GMK) | Executed an expedition to Eastern Greenland in 2012 and later exhibited the fossils and results. |
| Richard Østerballe | Givskud Zoo | Opened an animatronix dinosaurpark, Zootopia, in 2017, as an adjacent part of the Safari Park with living animals. |
| Henrik Johansen | Aalborg Zoo | The first Danish Zoo to exhibit dinosaur models, in the context of a zoological garden, in 2013. |

***Findings***

The findings imply that differences in the nature of reasoning between the seven respondents is correlated with the nature of the institution, albeit responses expressing economic factors as well as fascination factors were common to all respondents. The nature of the responses are elaborated subsequent to the following summary regarding the nature of the institutions.

The natural history museum of Copenhagen (SNM) and the Museum für Naturkunde in Berlin, both represented traditional natural history museums, conducting in situ research and preserving collections for display and study. They both expressed great value in the dissemination of authentic objects and research communication in their e-mail responses.

In contrast, the Experimentarium in Copenhagen represented a traditional science center applying *discovery pedagogy* and hands-on strategies, as was reflected in their responses. In contrast, both the Naturalis of Leiden and the Geocenter Møns Klint represented hybrid institutions combining characteristics of both the traditional museum and the traditional science center (McPherson, 2006). The difference is manifested in the dataset by the expression of an ontological approach of the hybrid institutions approximating the one of the traditional museum regarding the questioned dinosaur content, whereas the traditional science center – albeit displaying authentic objects did not consider them of any significant value, the discovery pedagogy of ‘learning by doing’ being the dominant ideology. Both hybrid institutions executed or participated in the excavations of the dinosaurs on display, and this might have influenced their affinities approaching a more museological nature.

Aalborg Zoo and Givskud Zoo both represented the traditional zoological garden, their authentic objects being not the dinosaurs on display, but the living animals. Their responses reflect a comparative use of extinct animals with modern animals and the modern world that is coherent with the mission and vision of zoological gardens to enhance preservation, interest and understanding of our natural world (Givskud Zoo_Masterplan 12446, Aalborg zoo.dk/naturbevaring).

In all the seven answers however, evidence was found of dinosaurs being chosen for their ability to ‘induce fascination in all age groups’ (Morten Meldgaard, SNM), and thereby enhance visitor-attraction, with derived benefits of ticket sale and/or learning motivation. This tendency was, in fact, already documented in 1907 by Franz Boas in ‘Some Principles of Museum Administration’. He describes how the American Museum of Natural History seeks to capitalize on the popularity of dinosaurs (Rieppel, 2012) and says that museums must: ‘first of all be entertaining’ and later that ‘…people will flock in crowds to the museum to see the specimen [a Diplodocus skeleton]’ (Boas, 1907). This combined wow-and-profit effect will in following chapters be referred to as the dinosaur factor.

Linda Galle from Museum für Naturkunde, Berlin says: ‘They [dinosaurs] are emotional objects and fascinate adults and children. But most of all they are crowd pullers. One colleague said: If you have Dinos, the people will come anyways’, and she later explains how: ‘One of the most important aims of the MfN is to get funding for a major renovation of the building and its collections, and continuously raising public attention is very important in that process’.

Asger Høeg from the Experimentarium in Copenhagen likewise describe the overwhelming success the first dinosaur exhibition prompted in 1997, attracting entire new segments of society to the Experimentarium: ‘Exactly the people Experimentarium wanted to attract. People that are usually not interested in natural science’. He thereby supports the conclusion of the disciplinary analysis of paleontology, that it contains the potential to attract different target groups than the ones usually attracted to science, thereby potentially increasing the diversity of science learners in general. However, Asger Høeg later elaborates how the audience ultimately reached a point of dinosaur saturation after four exhibitions within 12 years, enforcing new topics to emerge (the dinosaur topic was however re-introduced with the exhibition from the present study – 15 years after the first one in 1997).

The economic value of the dinosaur factor is in fact mentioned either directly (3) or implicitly (by accounting for the rise in visitor numbers) in 4 out of seven interviews and is naturally linked with the ability to attract paying visitors. ‘We were certain we could give our visitors a good experience, and also that we could attract a lot of extra visitors to make it a lucrative business for us - and we were right’ (Henrik Johansen, Aalborg Zoo).

The content-value, however, is described in differing terms, relating to the nature of the institution: The institutions conducting in-situ scientific research tend to use the dinosaurs for documentation of either scientific knowledge or scientific enterprise: ‘They are obvious objects to document an important era in Earth history, but objects are not much worth, if not presented in their scientific context' (Morten Meldgaard, SNM, Copenhagen).

Whereas the institutions presenting living animals tend to use them to compare ancient life with modern life: 'We use the dinosaurs in the dissemination of biological properties, but also use them to put the human influence of the natural world, and the human caused mass extinction that is happening, in perspective' (Richard Østerballe, Givskud Zoo).

However, one of the science centers express a similar strategy to that of the Zoos. Asger Høeg from the Experimentarium explains how modern animals were used to demonstrate a scientific point in their dinosaur exhibition: 'In the bottom of the exhibition was a henhouse. That made the visitors compare the claws of hens and chickens with the claw of the T.rex. In that way we taught the visitors, by their own curiosity, that birds are the distant gran-children of dinosaurs'. He thereby gives an example of an *authentic scientific inquiry* situation: Visitors intuitively using comparative anatomy between extant and extinct animals, to understand form, function and phylogenetic relationship of the latter.

The institutions presenting <u>authentic fossils</u> in their display, tend to associate the authenticity itself with high value. Nils Natorp from Geocenter Møns Klint explains that: 'We have a certain professionalism to defend, and there are plenty of plastic models all around – in our own exhibitions as well. So to do this with credibility, and make it part of our permanent exhibition which normally only deals with the Cretaceous time period and the white cliffs of Møn [the reader should note that the present dinosaur exhibition is about the Triassic of Greenland], it had to be "the real deal"'. Linda Galle (Museum für Naturkunde, Berlin) equally states that: 'We have several premises for our exhibition conception – one of them is to show original objects – we did that with Tristan [the T.rex]. The other one is, that the exhibition has to be linked with the research we do'.

Here, however, again there is the exception of the Experimentarium: 'To be honest I have to admit that the bones received very little attention, in their remote corner of the exhibition. Visitors in general do not distinguish between bones being authentic or replicas as long as you write honestly in the texts if they are replicas' (Asger Høeg, Experimentarium).

The significant contrast between the Experimentarium and the other institutions, is likely to be rooted in their pedagogical anchorage in the *discovery pedagogy* (Oppenheimer, 1968), whereas the remaining presenters of authentic fossils, all express a desire to fulfill a more classic museological role – even in the case of the two hybrid institutions (Geocenter Møns Klint and Naturalis in Leiden).

In sum, the disseminative strategies and approaches towards learning outcomes and visitor perceptions were located in a cross-section between the following 'poles':

1. Traditional natural history *museums* – and the appliers of *discovery pedagogy* or presenters of living animals.
2. Institutions conducting *in situ research* – and institutions only presenting scientific research (as products or processes).
3. Institutions displaying *authentic objects* – and institutions displaying either fossil replicas or animatronix dinosaur models.

In the following I discuss how these institutional 'poles', relate to the decisions regarding content and educational strategies within the range of exhibitions represented in the study.

***Discussion***

When observing the nature of the institutions in relation to the reasoning behind disseminating paleontology, a pattern of two institutional 'poles' emerges, as illustrated in the preceding. The museological 'pole' expresses an inductive reasoning with departure in *in situ research* as well as the collections of *authentic objects*. The opposite 'pole', however, expresses a more deductive reasoning with departure in the experience of the visitor. In the case of Experimentarium, an active engagement of visitors is prioritized over the experience of 'passively looking at fossils', (corresponding to the *discovery pedagogy* of science centers as defined by Oppenheimer, 1968). Additionally, the Experimentarium as well as the zoological gardens express the importance of the visitor experience to be based upon encountering the dinosaurs as 'real' animals, the animatronix models playing much the same role as the living animals of the zoo.

I initially expected the hybrid institutions to locate themselves somewhere between these two institutional poles, however they both expressed a desire to approach the museological pole, and to acquire the corresponding professional respect associated with the inherent research environment of a traditional museum. As earlier mentioned the fact that both hybrid institutions executed or participated in the excavations of the dinosaurs on display, is also likely to have influenced their affinities approaching a more museological nature, prioritizing objects and scientific process in the subjected dinosaur exhibitions, rather than the more principal hand-on exhibits dominating many of their adjacent exhibitions.

If deconstructing the above reasonings of the institutional poles into elements, they – as presented in the findings – emphasize either the importance of *authentic objects* and/or the dissemination of *authentic scientific inquiry*. As discussed in section 2.2, the discipline of paleontology holds particular potential for presentation of both of these elements, and the ontological status of ‘science in the making’ constitutes a corresponding strategy for disseminating the latter in exhibitions. In the following, I discuss the two elements with the existing literature on the subject, one by one.

***‘Science in the making’ as an approach to disseminating authentic science***

According to Schiele (2014), the ‘science in the making’ approach represents the beginning of a new era of dissemination strategy – especially in the science center and science museum context. He expounds that the science center, following its original ideology of making science accessible to the public (the 60s and forward), entered a second stage of bringing up socio-scientific topics (the 80s and forward), which is now slowly being replaced – or supplemented – by what he suggests to be a paradigm shift of science center dissemination. Meyer (2010) denotes science as ‘cold’ (objective, detached and free from ideology), when being presented to the public in the form of products, whereas ‘research’ he denotes as ‘hot’ (emotional appealing, engaging, passion mobilizing).

As a consequence of the elusive nature of knowledge still in progress, though, this approach also comes with a portion of risk, relating to the nature of the tentative results, the potential ambiguous, conflicting or disagreeing findings inflicting a possible insecurity in the visitor (Schiele, 2014). In this light, the institutions valuing dissemination of their own research – or their own participation in a scientific situation (like a dinosaur excavation), reflect a new tendency of combining scientific inquiry with the dinosaur factor and possibly with *authentic objects* as well.

***The importance of the authenticity of displayed objects***

The traditional museums have always valued *authentic objects*, due to their long historic of collecting and preserving them (Livingstone, 2003), as is also reflected in the above presented findings. However, two recent studies by Hampp and Schwann (2014/2015) put to question the visitor perceptions of the authenticity of original objects. Holtorf presented a new constructivist view in 2005, proposing that replicas – if only of a high-quality production – would have the same fascination power [in our case dinosaur factor] as the originals, provided the visitors were unaware of the replica status.

However, the studies by Hampp and Schwann find that – even when visitors *are* aware of the status of the object – the replicas are no less appreciated by the visitors than are the originals in the context of science exhibitions (~46% of visitors stated that the authentic status of an object mattered, while 47% stated that it did not). They also imply that certain expectations of the institution affect the perception of an object being authentic or not. In a museum exhibition, visitors expected objects to be authentic, and considered them as such, without checking against texts or explanations. Conversely, when subjected to objects of a special rare or fragile character, they presumed that those objects could not be authentic. In general, presumptions and expectations would determine visitor perceptions much more than texts and exhibition information on the matter of object authenticity (Hampp and Schwann, 2015). Consequently, they propose that objects should be combined with additional science-related information in relation to the object, allowing the physical experience of the object to connect with the cognitive experience, resulting in an enriched scientific understanding (Hampp and Schwann, 2015).

One might suggest that this science-related information, in the case of dinosaur exhibitions, could be a presentation of ‘science in the making’, to take full advantage of the unique affinities of paleontology. This is evidently what has been done by several of my institutions of study, including both the natural history museums and the science centers. Ultimately this indicates that the combination of ‘science in the making’ and ‘authentic objects’, has the potential to enhance the unique disciplinary qualities of paleontology, and – in further combination with the dinosaur factor – it contains the derived effect of attracting more visitors to the exhibitions.

In the following chapter, I shall investigate the genesis of a dinosaur exhibition in one of the hybrid institutions, Geocenter Møns Klint, who has used the strategy of combining 'science in the making' with authentic objects in the exhibition design. I intend to study the external and internal factors that might have been of influence to the final product, and to investigate whether such a design process can be optimized to reach the intended visitor learning outcomes.

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# Chapter 3
# The Genesis of a Dinosaur Exhibition

In the following I describe the design process of a dinosaur exhibition called 'The First Dinosaur' which was developed at Geocenter Møns Klint. It was designed in 2012-13 and opened in June 2013. The exhibition was born as a result of an expedition to Eastern Greenland in 2012 and was an attempt to document the discovered fossils but also their unearthing, transportation and preparation[1]. Ultimately, the design process even involved using the fossils to produce 3D-reconstructions of the prehistoric animals for display in the resulting exhibition. This chapter will study the genesis and creation of 'The First Dinosaur' in an attempt to understand the influences and constraints that potentially affect not only the exhibition's design, but also the content and scientific knowledge disseminated in the displays (cf. Achiam and Marandino, 2014). The results will ultimately contribute to the final understanding of the interplay between paleontology as a scientific discipline and its role in dissemination and exhibition design.

## 3.1 Background

At Geocenter Møns Klint, the white cliffs of the island of Møn are the primary topic of dissemination because they represent one of the best locations to observe and study the geological foundation of Denmark which consists of limestone and chalk from the Cretaceous time period (The Cretaceous is the last period of the Mesozoic, also known as the 'age of dinosaurs'). To introduce new content and experiences to visitors, however, the managing director, Nils Natorp, was interested in displaying additional geological material from the Mesozoic and further, in presenting the visitors with the most iconic beings from this time period – the dinosaurs. His rationales are discussed in the preceding section (Chapter 3) and are partially based on the 'dinosaur factor' and partially on the thematic coherence between the age of dinosaurs and the geological age of the locality at the white cliffs.

[1] Fossil preparation is the process in which the sediment imbedding the fossil (the matrix), is gently removed, to expose the fossil in its entirety.

Through his geological network, Nils Natorp became aware that a Triassic (earliest period of the Mesozoic) locality in Eastern Greenland on Jameson Land contained dinosaurs as well as other extinct animal groups (including Pterosaurs, Aetosaurs and Cyclotosaurs), and the decision was made to make this Triassic locality a new geological topic of dissemination at Geocenter Møns Klint. The Jameson Land locality represents the first dinosaur locality discovered within the Danish realm (Jenkins et al, 1994). It was found and described by a succession of expeditions in the 80s and 90s, whereas the first dinosaur fossil in Denmark proper was found almost 20 years later on the island Bornholm in 2000, as mentioned in the introduction (Christiansen and Bonde, 2003). Nils Natorp therefore named the project 'The First Dinosaur'; this title also acknowledged the fact that the dinosaurs found in the Jameson Land locality represented some of the very earliest dinosaurs. Indeed, the Triassic is the oldest Mesozoic period in which dinosaurs occurred.

Geocenter Møns Klint, led by Nils Natorp, planned and carried out a new expedition to the dinosaur locality of Jameson Land. The explicit purpose of the expedition was to use the discoveries for the subsequent development of an exhibition that would display the newly discovered fossils as well as the expedition itself. The expedition to Jameson Land took place in July 2012, and it was documented in its entirety by recordings, photos and interviews for the purposes of the future exhibition. Even tools and artifacts from the expedition would later go on display, along with of course the fossils – the actual scientific products – from both the new and the previous expeditions.

### 3.1.1 Previous expeditions and findings

As mentioned in the preceding, the 2012 expedition was to follow up on a line of expeditions to Jameson Land in Eastern Greenland that took place in the 80s and 90s. These previous expeditions were carried out by Harvard University in cooperation with Danish geologists from the University of Copenhagen, and many fossil specimens from these expeditions were consequently stored at Harvard University, being officially 'loans' from Denmark, since anything found in Greenland in the time period in question would belong to the Danish state. On the request from Geocenter Møns Klint, Harvard University agreed to return to Denmark the fossils discovered on previous expeditions. The Geological Museum of Copenhagen, which is part of the Natural History Museum of Denmark, took ownership of these fossils but agreed to display them at the Geocenter Møns Klint for a number of years. The original Danish expedition leader and sedimentologist, Lars

Clemmensen, who instructed Harvard University in the geology of Greenland, even agreed to return to Jameson Land to be the leader of the 2012 expedition.

The previous expeditions had found bones from many different animals, most importantly an almost complete prosauropod, the *Plateosaurus,* in 1991 (Jenkins et al., 1994). The Plateosaurus was one of the first dinosaurs to reach a considerable size (see fig. 3.1); its descendants later became the long-necked sauropods of gigantic body size known from many books, TV-shows and movies about dinosaurs (see fig. 3.2). The Plateosaurus was therefore chosen as main character of the exhibition, and the 2012 expedition consequently aimed directly at finding new Plateosaurus bones.

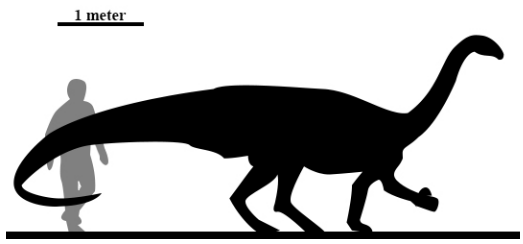


**Fig. 3.1.** Plateosaurus in quadruped position.

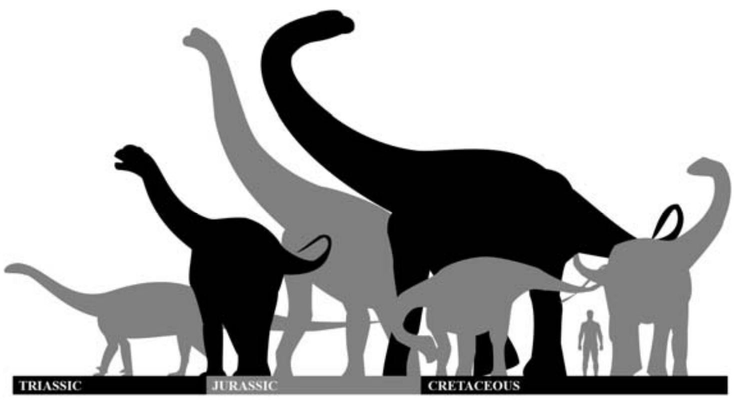


**Fig. 3.2.** Timeline and scale of sauropods and a Triassic prosauropod relative of the Plateosaurus.

The 2012 expedition successfully found more *Plateosaurus* material, but it also found other species, most importantly a very well-preserved specimen of the rare group of extinct crocodilian relatives called phytosaurs (Clemmensen *et al.*, 2016). After returning home, the preparation of the specimen revealed the bones to be from not one, but several individuals. This distinction was made on the basis of the presence of at least three humerii (upper arm bones), and bones of various sizes, including a very small shoulder blade from a juvenile phytosaur.

Since phytosaurs are very rare fossils globally, the discovery of multiple animals of different sizes and ages was extraordinary. The expedition team suspected that more fossil material might be located at the site and wanted to return to investigate further. In 2016, Geocenter Møns Klint thus organized a second expedition, and a select group of the original team members returned to Greenland for further excavation (see chapter 5). The exhibition resulting from the expedition 'The First Dinosaur' was designed and opened in 2013, and in 2017 a new exhibition element based on the 2016 expedition was added. In the following, I consider only the design process of the exhibition that opened in 2013; the newer exhibition element that was added in 2017 is considered as a separate case study in the final section of the dissertation.

### 3.1.2 The Development of the Exhibition

In the following, I investigate and analyze the development process that led to the production of the exhibition 'The First Dinosaur'. This analysis attempts to answer the first part of research question 2 (bolded here; the second part of research question 2 will be addressed in the last section of the dissertation):

> **RQ2**: **Which factors affect the design process of exhibitions**, and how can such a design process be optimized so that the integration of a specific disciplinary knowledge and the exhibit elements allow visitor outcomes to correspond to as well the disciplinary potential as the original designer goals? What kind of strategy can be applied to achieve such goals?

## 3.2 Theoretical Framework

In my analysis of the design process, I employ the notions of *didactic transposition* and the *hierarchy of levels of didactic co-determination* (in the following: 'the levels of co-determination') to understand how constraints and conditions affect an exhibition design process as well as its palaeontological content in an institution specialized in geology dissemination, namely Geocenter Møns Klint. As mentioned in Chapter 1, the framework of levels of co-determination is part of the on-going development of the Anthropological Theory of Didactics (ATD) by Chevallard (2002) and others. Despite its origins within ATD, which is a research programme firmly established in the didactics of mathematics, the levels of didactic co-determination have recently been adapted by Achiam and Marandino (2014) to fit science museum institutions.

In their adaptation of the framework to museum contexts, Achiam and Marandino (2014) make several observations of museum institutional practice. First, they observe that science exhibitions and the processes of creating such exhibitions are disjunctive of nature. They explain this disjunction by discussing how the creation of exhibitions involves the transformation of scientific content, which is usually rooted in or originating from a scientific discipline, into the disseminated content in the exhibition. This means that before it is put on display, disciplinary content undergoes pedagogical, physical and other adaptations to make it fit the intended receivers of the knowledge (i.e. the visitors) in the physical format of an exhibition. As discussed in Chapter 1, it is this transformation of scientific knowledge that constitutes the fundamental didactical phenomena denoted and described by Chevallard (1991) as the *didactical transposition* (fig. 1.2.), and that is modified into what is designated as the *museographic transposition* (fig. 1.3) by authors such as Simonneaux and Jacobi (1997), Gouvêa de Sousa et al. (2002) and Mortensen (2010).

Studies of didactic transposition in museums illustrate the multitude of different conditions and constraints that co-determine the creation of exhibition content. For example, even though she does not use the term didactic transposition, Macdonald (2002) discusses how the collections of a science museum co-determine the contents of its exhibitions, while Mortensen (2010) gives examples of how the everyday knowledge of exhibition designers can influence the content of the final exhibit. Similarly, in Chapter 2 of this dissertation I exemplify how the type of institution co-determines the rationales for exhibiting dinosaurs.

It was for the purpose of discovering and categorizing co-determinants such as these that the levels of didactic co-determination emerged in ATD. In other words, the levels of co-determination were developed by Chevallard (2002) and others (e.g. Artigue & Winsløw, 2010) to understand and systematize the diverse range of conditions and constraints that govern the didactic transposition of mathematics content and practices; the framework has since been adapted to the museum context as well (Achiam and Marandino, 2014).

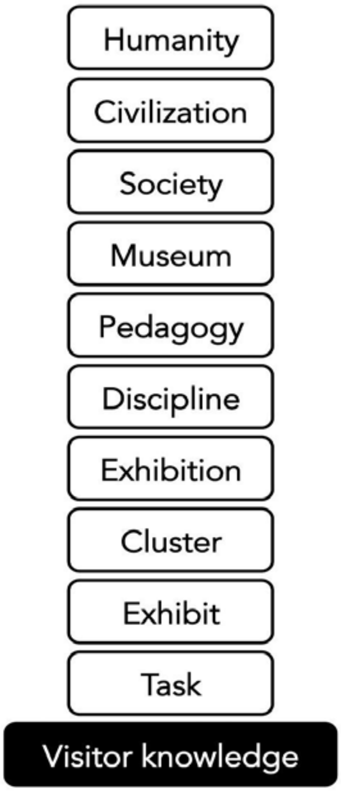


**Fig. 3.3.** The adaptation of the hierarchy of levels into a museum context (from Achiam and Marandino, 2014)

As seen in fig. 3.3, the levels of didactic co-determination are positioned in a hierarchy comprising external factors (levels 8-10), internal factors (levels 5-7) and local factors (levels 1-4). In the following, I briefly describe the levels of co-determination that influence the transposition of knowledge within exhibition design. This description is based on Achiam and Marandino (2014, forthcoming) and illustrated with examples from research.

The highest levels of co-determination, i.e. **humanity and civilization** (levels 9 and 10) play perhaps the most elusive roles. However, the history of the museum as an institution follows the history of our western civilization. The very first *mouseions* (temples of the muses) were born in ancient Greece, along with western civilization itself (Mairesse, 2010), and in the 16th to 18th centuries, Europeans travelled to the New World and brought back numerous *exotica* to display to the aspiring ‘enlightened[2]’ public in *cabinets of curiosity*.

Both natural history and the museums as we know them today were born as these curious objects gradually became objects of research (Baron, 2004; Livingstone 2003). Indeed, museums have continued to reflect the scientific movements of humanity and civilization as new disciplines, theories, paradigms and most recently – pedagogies – have arisen. Indeed, this co-development has prompted the birth of new museum institutions in the form of science centers, science and technology museums, etc. (see also Chapter 2 about out-of-school contexts).

**Society**: Conditions and constraints that originate at the level of society are perhaps easier to observe. Today, many museum initiatives are dependent on subsidies from sponsors and private foundations (McPherson, 2006); these entities co-inhabit the same society (nation) as the museum yet are external to it. Further, state-owned institutions such as national museums must live up to certain regulations (in Denmark defined by the Ministry of Culture or the Ministry of Education), and many privately-owned institutions are equally dependent on state funding. These institutions thus have to meet certain criteria to receive economic support. The Danish VPAC subsidy system (Pedagogical Activity Centers) is one such example of a state funded scheme that supports an array of out-of-school dissemination centers with different areas of specialization such as iron age archaeology or the geology of a specific location (such as Geocenter Møns Klint). Moreover, a system of private non-profit foundations (Thomsen, 2017) exists in Denmark. These foundations have committed themselves to supporting education and dissemination initiatives (among other things), making them important economic contributors to many Danish cultural or scientific projects, such as for instance science museum exhibitions.

Turning now to conditions and constraints that originate inside the museum institution, we find the levels of museum, pedagogy, and discipline (levels 5-7). Conditions that originate at the **museum** level are those that can be ascribed to the nature of the institution. The aforementioned example of how the content of a museum’s collections may co-determine the contents of its exhibitions (Macdonald, 2002) illustrates a constraint at the museum level.

[2] The Age of Enlightenment and the ‘scientific revolution’ were intellectual and philosophical movements, that aimed at introducing reason and systematic thinking as the primary source of legitimacy in the 18th century.

Conditions that originate at the **pedagogy** level are those that arise from its chosen pedagogy, for instance the discovery pedagogy typical of science centres (cf. Crain, Loomis & Ogawa, 2013) or the object-based pedagogy typical of natural history museums (cf. Conn, 2010). Finally, the academic **discipline** from which the disseminated subject originates contains certain qualities that may *a priori* condition or constrain the content presented in exhibitions. Examples of such conditions are discussed in Chapter 2 of this dissertation; for example, the nature of paleontology as a mainly inductive science conditions the way it can be embodied in exhibitions and the learning trajectories it can give rise to. Some museums specialize in one discipline, as for instance the geocenters which disseminate (local) geology; others specialize in broader scientific domains, as is the case with natural history museums or national museums.

Whereas the conditions and constraints that originate at the hierarchical levels from humanity to discipline relate mainly to the content-selection process in exhibition design, the conditions and constraints at the levels from exhibition to task more directly co-determine the content-*embodiment* in the physical installations of the exhibition. These local levels are denoted as: the **exhibition** (level 4), presenting a certain theme or topic that usually originates within an academic discipline or number of related disciplines (an interdisciplinary topic could, for instance, be climate change).

The levels within the exhibition then usually consist of thematic **clusters** (level 3) of various **exhibit elements** (level 2) making use of certain **tasks** (level 1) to familiarize the visitor with the topic by use of pedagogic strategies of either interactive or informative nature (e.g. button pushing or label reading as exemplified by Achiam and Marandino, 2014).

Finally, at the very fundamental level of **visitor knowledge** originates conditions and constraints related to the established knowledge and predispositions of the visitor (level 0). In the constructivist view of learning, this knowledge and these predispositions are the most basic co-determinants of the science that is acquired or lived by learners in any educational situation (Hein, 1998; Anderson *et al.*, 2003).

## 3.3 Method

To investigate the didactic transposition of paleontological science-in-the-making from expedition to the exhibition 'The First Dinosaur', I conducted semi-structured interviews with my four co-designers during the spring and early summer of 2017. These interviews were transcribed and coded by the method of thematic analysis described by Braun and Clark (2006), using a top-down or deductive approach to identify conditions and constraints based on the hierarchy of levels of co-determination.

The interview questions were generated as a chronological examination of first, the design process, and second, its product – the exhibition. The first question was a non-structured request to narratively explain the design process as it was recalled by the individual designer. In applying this narrative methodology, I expected individuals to spontaneously mention constraints or conditions originating at any level of co-determination. In this way, significant co-determinants including those pertaining to the scientific expedition itself would be revealed either consciously or unconsciously as the story of the development process sprang to mind (Gabriel, 2004). In the subsequent semi-structured questions, I asked the designers about their individual roles in the design process as well as their expectations with respect to the exhibition and its learning goals, and ultimately, whether these expectations were met in the final result.

### 3.3.1 The exhibition

The overall design of the exhibition is laid out as a chronology from the expedition (scientific process) on the lower floor and in the stairways, to fossils and dinosaur reconstructions (scientific products) on the upper floor. The first room thus presents the expedition to the visitor. The expedition team and the work and practices of paleontologists are presented on video touch screens. Landscapes from Greenland are used as wallpaper for this room, and authentic, fossilized dinosaur footprints from the Jameson Land locality are displayed without cover, for the visitors to touch. In addition, an interactive map of Greenland indicates the exact location of the two campsites and excavation sites of the expedition with multiple photos.

Moving through the exhibition, the stairways first present video recordings from the previous expeditions, and then from the 2012 expedition, including subjects such as camp life, polar bear protection, excavation techniques and fossil transportation. On the upper floor where the discovered fossils are displayed, the first thing that meets the visitor is a pair of running machines (similar to exercise treadmills). They invite the visitors to run like dinosaurs with erect leg posture (running machine 1) or like phytosaurs with sprawling leg posture (running machine 2) as seen in fig. 3.4. The activity illustrates that running like a dinosaur with erect leg posture is much easier and demands much less energy than running like a phytosaur in a sprawling position. This potentially explains why dinosaurs ‘won the race of evolution’ and survived, while many other animal groups – such as the phytosaurs – went extinct at the end of the Triassic time period, after which the dinosaurs dominated the Earth for millions of years.

**Fig. 3.4.** ‘Run like a dinosaur or a phytosaur’ in ‘The first dinosaur’

Next, the ‘fossil room’ presents the visitor to display cases with authentic fossil bones from the recent as well as the previous expeditions. Each fossil is moreover presented on an interactive touch screen with a 3D animation of the animal, a size scale (compared to human) and an indication of the physical location of the displayed fossil(s) within the reconstructed animal. The visitor can turn the reconstructed animals around by touching and dragging them, as well as activating layers of information from selected ‘touch-spots’ on the animal.

The last room presents the ‘Grande Finale’ and the Plateosaurus. The near-complete 1991 specimen of the Plateosaurus lies on one side of the small room, while a full-size model of the skeleton stands on the other side. Big wall size screens loop between a landscape of modern Greenland and a 3D animation film of the Triassic, complete with the extinct animals presented in the ‘fossil room’. At the end of the loop lights go off and suddenly another [mirror]-screen lights up and shows the erect Plateosaurus model growing flesh and blood and coming alive, by means of augmented reality.

The ‘mirror-screen’ allows the visitors to see themselves interacting with the Plateosaurus, until a phytosaur suddenly appears and kills it. The Plateosaurus dramatically dies on the screen, as the authentic fossils light up again and illustrates its bones.

**Fig. 3.5.** Augmented reality with the Plateosaurus ‘coming alive’

### 3.3.2 The design team

The design of the exhibition ‘The First Dinosaur’ took place as a collaboration between five people, myself included, from the beginning of 2012 (before the expedition) until the opening in June 2013, one year after the realization of the expedition. The team members had different professional backgrounds. The disciplinary knowledge thus came mainly from external consultants, whereas internals were responsible for logistic and practical functions.

**Table 3.6.** Team members in the exhibition design workgroup.

| Team member | Position |
|---|---|
| Nils Natorp | Managing director (overall responsibility and funding) |
| Maks Bragt | Project manager (construction and technology) |
| Nadia Rosendal Nielsen | Project manager (communication and content) |
| Jørn Waneck | External consultant (geologist) |
| Eliza Jarl Estrup | External consultant (paleontologist) |

### 3.3.3 Insider role

Being a co-designer myself in the process under investigation naturally raises some issues worthy of reflection. Adriansen and Madsen (2009) describe this role as that of a *double insider* referring both to the subject of study (in my case the exhibition and its design process), and to the interviewees (in my case the other team members of the design process). They describe how this insider role is rare within the field of geography (the authors’ discipline of study), as well as in other natural sciences. However, as they observe, this role is much more common in fields like anthropology, where being an insider is often seen to be advantageous rather than disadvantageous, with a greater knowledge of the context, shared outlook, etc. Nevertheless, the role is complex, and often contested throughout the research process, one of the disadvantages being the lack of distance to the field of research (Adriansen and Madsen, 2009).

In the case of 'The First Dinosaur', the research situation I found myself in is somewhat similar to that of an anthropological study that investigates the dynamics and influential factors of a group of people rather than natural phenomena. However, it cannot be denied that my personal involvement in the process might have given rise to preconceptions or esoteric answers. I have tried to avoid these faults by drawing conclusions exclusively from interview data, while at the same time using my personal knowledge as a buffer for informed knowledge.

## 3.4 Findings

I found conditions and constraints to the exhibition design process at every level of co-determination, excluding the uppermost level of humanity and civilization. In the following, I describe the conditions and constraints on each level, and discuss how they affected the final exhibition.

First, I found no explicit evidence of conditions and constraints at the levels of **humanity** or **civilization** to have influenced the design process. The institutional-hybrid nature of Geocenter Møns Klint, however, places it partially in the museum tradition of 'enlightening' the visitors by displaying scientific products (Hooper-Greenhill, 1999), and partially in the science center tradition of 'educating' the visitors by encouraging them to experience scientific phenomena (Oppenheimer, 1968). Both traditions could arguably have had indirect influence on the fundamental attitudes towards exhibition design and learning outcomes of the design-team members; however, this was not discussed in the interviews.

In contrast, conditions and constraints to exhibition design that originated at the level of **society** were highly evident in the interviews with all four design team members. Four different kinds of societal conditions were observed, namely those related to the *financial aspects* of the exhibition, those related to *national cultural heritage*, those related to *collaborations with other institutions*, and those related to societally mandated *restrictions on construction*.

The managing director, Nils Natorp, primarily discussed the financial aspects. He explained how new projects are dependent on economic funding, and how consequently, the initial idea for 'The First Dinosaur' was dependent on its ability to convince industrial foundations that it was good as well as profitable. Jørn Waneck (geologist) mentioned a similar constraint, but from the perspective of the content-developer:

> …it was typical of Nils that before he even had the professionals involved, he had already planned a whole lot which had to be implemented, because it was described in the original applications for the foundations providing the money.

Nils Natorp additionally discussed the level of society more directly in the form of the Danish cultural identity and heritage:

> There was an ambition of making it a story of 'the first Danish dinosaur-skeleton', which gave rise to the original concept in the applications. It was called 'The first dinosaur' because I then believed that we could turn it into a national event.

Nils Natorp later explained how that ambition was partly fulfilled, but how the American *Diplodocus* Misty that was acquired and put on dislay by the Natural History Museum of Denmark (SNM) in Copenhagen ended up in the public's awareness as the 'Danish dinosaur'. This example reveals a tension between the large, nationally funded natural history museum in the nation's capital and the much smaller, private-foundation dependent museum in the countryside. This tension arguably illustrates how, perhaps implicitly, higher status is conferred to the older, more traditional and well-established natural history museums by society as well as in the eye of the public. The same tension continues in the description of the initial cooperation between the two institutions by Jørn Waneck (geologist):

> There was a hell of a lot of trouble, for example because at the highest level the SNM had approved [for GMK to borrow the fossils from Harvard University], but they had not informed the lower levels. So, when Nils and I met the conservator, he did not know anything […], and he was very unfriendly.

The relationship between GMK and the conservator of the SNM, however, turned out positively in the end, and Nils Natorp later described network connections with other research communities as positive and essential for the realization of the project. Nadia Rosendal Nielsen (project manager) even indicated that in ‘The First Dinosaur’, ‘science is still in the making’ due to new series of studies of the displayed fossils commenced by an Italian PhD student (a new network connection established through the project). These studies allow visitors to observe the PhD student mounting and dismounting the fossils in the exhibition when he needs them.

Finally, the physical framework of the exhibition was also conditioned by certain societal limitations. Maks Bragt, who was responsible for construction and technical solutions, described how the early phase of exhibition design was constrained by the construction of exhibition spaces inside a building of historic interest; however, this constraint was not mentioned by any of the other designers.

Evidently an array of economic, physical, cooperative and emotional connections to the surrounding society all co-determined the design process of ‘The First Dinosaur’. In the following, I discuss how internal conditions and constraints were important. In other words, I discuss how Geocenter Møns Klint itself offered conditions and constrains to its internal process.

At the **museum** level, Geocenter Møns Klint is a member of the VPAC institutions (Pedagogical Activity Centers) as mentioned in Chapter 2. This means that it receives subsidies from the government to fulfil certain educational criteria. The conditions for meeting these criteria include ‘activating’ the visitors, while ‘educating’ them (Ministry of Education, 2000); for many of the VPAC institutions, this translates into a hands-on, discovery pedagogy similar to that of many science centres (discussed in the following section). However, in the case of Geocenter Møns Klint, a complex interaction between the research-oriented world of museums and the more interactive world of science centers (and their corresponding discovery pedagogy), is evident in the data material. As pointed out by directing manager, Nils Natorp, when referring to the layers of scientific knowledge available through the touch screens in the exhibition:

> That is again the professionalism we need to express to maintain the scientific level, and we also need a little professional respect, right. We are only a science center or a discovery center, and therefore it might be extra important for us to have the positive feedback of being true to the discipline.

He further explains how the contact with established research institutions in Copenhagen is even written into the institutional concept as an obligation. This, he explains, is a consequence of the Geocenter not being a research institution itself but nevertheless aiming at disseminating scientific knowledge that is up-to-date and represents the state of the art. Indeed, despite being a 'non-research' institution, Geocenter Møns Klint *did* plan and execute a scientific research expedition to Greenland, and consequently decided to disseminate the expedition and the entire scientific process of finding, excavating, transporting and preparing the fossils in the exhibition.

As described in the preceding, with respect to its **pedagogy**, Geocenter Møns Klint positions itself in between traditional museological principles and interactive science center principles, creating a pedagogical mix, which is evident in several of the interviews. Nadia Rosendal Nielsen (project manager) described the fossils – the objects – as the 'crown jewels' of the exhibition in the following way:

> Fantastic room, with the fossils. That is the more museological part […] it is like entering a jewel shop, the fossils appearing expensive and special.

She further describes the Plateosaurus climax as

> …a kind of dinosaur cathedral' […] they (visitors, red) are very fascinated by the authentic bones. It is important that they are authentic, and a lot of people ask about it.

All four designers mention the interactive presentation of texts and information on touch screens as important pedagogical features. Almost all text and knowledge in the exhibition is presented on touch screens, with only a basic presentation on the 'front page'. The visitor can then touch the elements they wish to know more about. In the case of the 3D animation screens that accompany the fossils, visitors can activate points of special interest of that particular animal. Touching the teeth of the animated phytosaur, for instance, activates a text about the diet of the phytosaur, as expressed by the nature of the teeth. All the designers agreed that it was important to design these layers of information in a way that did not overwhelm the non-scientific visitor, but at the same time met the expectations of visitors with detailed scientific interests:

> Then you can present a 'deeper story' to those who want it and a relatively clean appearance for the visitors passing by only looking at the glass cases (Maks Bragt, technical manager).

Considering how Geocenter Møns Klint is more similar to a science center than a museum, it is striking that none of the designers mentioned the 'run-like-a-dinosaur' activity in more than descriptive terms. As described in the preceding, the two running-machines allow the visitors to run with the leg position of either a dinosaur (erect position) or a crocodilian phytosaur (sprawling position) to illustrate one of the adaptive advantages of dinosaurs and why they ended up becoming more successful than the phytosaurs. It is the only activity in 'The first dinosaur' making explicitly use of *discovery pedagogy*, however, it is not emphasized as of particular importance in the interview material, again indicating an (unconscious?) aim at approaching a more museological strategy of disseminating research, rather than encouraging 'visitor activity'.

**Discipline (level 5):** Given its nature as an institution with a core competence of disseminating local nature and geology, Geocenter Møns Klint has evident obligations towards geology as a discipline. All designers agreed that this was the main reason – and the eligibility – to find and excavate a dinosaur, even though it did not originate at the geological locality of Møns Klint. Nadia Rosendal Nielsen says '…then you can say that dinosaurs are connected to the time period we disseminate here, so it makes good sense', and Nils Natorp says: 'Since our job was to disseminate geology, nature and fossils, I was of the belief that we had to have a dinosaur!'

Nadia Rosendal Nielsen even pinpoints that the dinosaur expedition to Greenland (the scientific process), had a direct influence on the design process:

> So the entire process of planning the expedition and talking to the scientists, getting all the scholarly inputs and creating the reference material for the exhibition, etc. was all mixed up! It all mixed up so that the expedition actually ended up being part of the design process.

She later elaborates how it was part of the original goal to display the procedural aspects of the expedition:

> It was a balance between disseminating some scientific procedures – we wanted to present how paleontologists work, but also the 'adventure' connected to that procedure – and at the same time get some scientific points through in an 'edible' way for people to understand. That made it really exiting.

Nils Natorp ultimately explains how the 'Grande Finale' is important in the dissemination of science in the making: '[Science in the making] is exciting, if you can have a great finale. If not, it can become to 'curly' [difficult to grasp], I think. I really think science in the making should be thought through, because there needs to be a big carrot in the end – and that is where you can take advantage of the dinosaur effect – to apply some scientific understanding, as we also saw in the Trix exhibition recently' (in the utterance, Nils Natorp refers to a recent study trip by staff members from Geocenter Møns Klint to Naturalis, the Netherlands).

The last levels of co-determination: **Exhibition, Cluster and Task** will be considered in the presentation of the exhibition as a (final) product in the comparative analysis in the next section, as well as the final level of **Visitor knowledge**, which will play an integral role in the evaluation of the exhibition product in relation to visitor outcomes (Chapter 4).

## 3.5 Discussion

Although all levels of co-determination (except humanity and civilization) are represented in the findings, they are not distributed equally amongst the designers. Nils Natorp (managing director) discusses conditions that originate at the level of society more than any of the other designers do, whereas Maks Bragt, who was responsible for internal construction, emphasizes conditions and constraints at the institutional level of the museum. Correspondingly, Nadia Rosendal Nielsen and Jørn Waneck, who were responsible for the educational content, both emphasize the pedagogical level to a high degree. Only the level of discipline is seemingly subject to much emphasis from all four designers (this level will be treated independently further down).

This pattern corresponds to what Artigue and Winsløw calls the 'teacher's confinement'. It parallels the example from the formal school system of the individual teacher not being able to substantially change teaching practices beyond the level of *theme* (Barbé *et al*., 2005), whereas e.g. curriculum developers do have the power to affect higher levels of pedagogy, topics of teaching or even practice of teaching (Artigue and Winsløw, 2010). In the museum world Achiam and Marandino (2014, p. 78) similarly describe how

> …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.

Figure 3.7 illustrates how these different levels of influence was distributed in the design process of 'The first Dinosaur' on Geocenter Møns Klint, and how this corresponds to the individual areas of responsibility (in parenthesis).

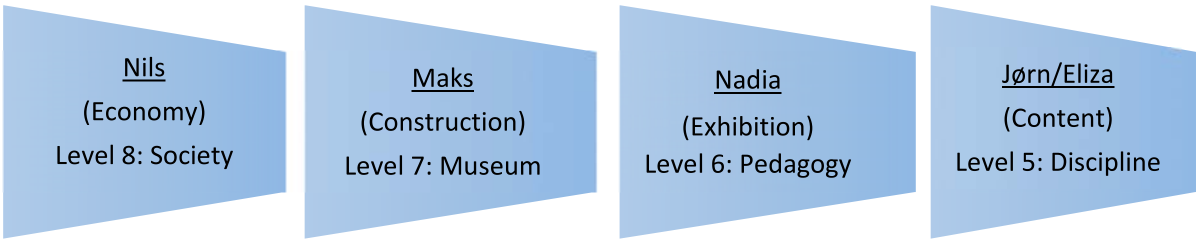


**Fig. 3.7**. Distribution of the levels of co-determination amongst the exhibition designers.

It is important, in this regard, to note that all team-members expressed how they had played a central and important part in the design process *and* that the atmosphere in the team had been harmonious and pleasant. This suggests that none of the levels of fig. 3.3. were neglected to the benefit of commercial interests, in spite of their higher decisive influence. The fact that everybody felt central and important to the process possibly reflects that the competencies of each team member supplemented each other with minimum overlap, such that each individual task corresponded to a specific co-determination level, thereby reducing potential conflicts of interest. Lindauer (2005) explains lack of conflict in exhibition design teams by the presence of a shared game plan between 'curriculum theories'. In contrast, Lee (2007) describes collaboration between individual competences as an interplay between different 'communities of practice'. Lee discusses how such communities of professionals with different backgrounds, roles or expectations, have the potential to cause conflict or misunderstandings among team members.

Accordingly, I suggest that the reason that this did *not* happen in Geocenter Møns Klint might be found in the minimal overlap between the individual tasks and areas of responsibility (as illustrated by fig. 3.7).

Most strikingly in the interviews, however, is the ubiquitous emphasis on the level of *discipline*, expressed by all team members. As described in the preceding, Geocenter Møns Klint is an institution with a specific aim to disseminate the geology of the local area, and therefore the institution has deep roots in the discipline of geology. The findings suggest that a feeling of inferiority towards 'traditional museums' is present, and that the identity of the Geocenter, even though it contains many features of *discovery pedagogy* in the permanent exhibition, attempts to become a more museological institution in this new dinosaur exhibition. This tendency is evidenced by the institution's increased focus on objects ('crown jewels'), and scientific practices – or science in the making - that give these objects meaning (cf. Bain & Ellenbogen 2002).

Another consequence of the strong influence of the discipline of geology is that the design process became very plastic and flexible. This was explained by Maks Bragt and Nadia Rosendal Nielsen as the confluence of the timelines of the expedition (the scientific process) and the design process; in both cases with outcomes and processes that only gradually unfolded. At the same time, however, the economic constraints originating outside the institution made it a very inflexible process (as especially pointed out by Jørn Waneck and Nils Natorp), since many features were already pre-determined by the promises made to the funding industrial foundations.

In sum, the data suggest that the design strategy of 'The First Dinosaur' is based on a more inductive pedagogy (based on objects and discipline, as is usual in traditional museums), while the permanent exhibitions at Geocenter Møns Klint, which disseminate the geology of the white cliffs of Møn, are based on a more deductive approach (*discovery pedagogy*) as is typical of science centers and other VPAC activity centers. The unique characteristics of paleontology as a discipline might have had an influence of this variation on the usual institutional practice, since these characteristics include 'museological' features such as spectacular authentic objects and captivating authentic scientific inquiry, as discussed in Chapter 2.

In the following chapter, I will compare the exhibition ‘The First Dinosaur’ with a corresponding dinosaur exhibition ‘Follow the Track’ at the science center Experimentarium in Copenhagen to investigate whether the inductive approach identified in the preceding is linked to paleontological content, even when this content is disseminated in a traditional science center such as the Experimentarium. I will also attempt to understand to what extent a traditional science center implements the strategy of ‘science in the making’ differently than a hybrid institution such as Geocenter Møns Klint, and especially how such differences are then expressed in the resulting visitor outcomes of each institution.

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# Chapter 4
# Visitor outcomes

The preceding chapters have outlined and investigated the design process and creation of the exhibition ‘The First Dinosaur’. Subsequent to the creation and opening of this exhibition at Geocenter Møns Klint, I conducted a visitor study. The primary purpose of this study was to understand the effect of the ontological status of the paleontological content (as ‘science in the making’), as well as the unique status of Geocenter Møns Klint as a hybrid museum with features of both traditional museums and science centers. A supplementary study with a second dinosaur exhibition in a typical science center, the Experimentarium, was carried out to compare their educational features, as well as their visitor outcomes.

The present chapter is divided into three sections that investigate the learning outcomes of visitors in different ways. Two sections describe the comparative analysis by means of written surveys and semi-structured interviews, respectively, and a third section describes an additional study in which I observe visitors to one specific exhibition element in the Geocenter Møns Klint.

Visitor outcomes could potentially be measured in countless ways, including emotional experiences, gained factual knowledge, long-term memories and enhanced understanding of one or more subjects (cf. Rennie 2007). In the current study the concept of *scientific literacy* has been utilized to assess visitor outcomes. As explained in the following, I pay particular attention to scientific literacy as what Roberts (2007) defines as its ‘Vision II’ sense, which is a more attitude-based approach to science. This is in contrast to the original ‘Vision I’ sense, which is also known as *science* literacy and expresses a competence or understanding of a specific scientific practice. In the following, I outline the different definitions of scientific literacy.

## 4.1 Scientific literacy

Many interpretations and definitions of the term have contributed to the study of *scientific literacy* through time (Miller, 1983; Durant, 1993; Shamos, 1995). It is most often described in terms of public understanding of the knowledge, terminology and procedures of science (Durant, 1993; Henriksen and Frøyland, 2000; Laugksch, 2000). As mentioned in the preceding, an important distinction is made by Roberts (2007), who points to two levels of scientific literacy: *Science literacy* – or Vision I – which is defined in its original meaning as the ability to understand and use science in a scientific way that is mostly relevant for scientists or people working directly with science. *Scientific literacy* – or Vision II – is defined in a much broader way as a basic understanding of scientific mentality, wide enough to be translated into everyday use of science in general life, or as a tool for making democratic decisions with respect to a society built on science and scientific products (Roberts, 2007).

Sjøberg (2005) enriches the distinction between Vision I and Vision II with his arguments for the pursuit of public scientific literacy. In Sjøberg's view, both Vision I and II have an individual as well as a communal component. Thus, Vision I can be described as the need to understand and use science for the profit of either the individual (the *practical* criterion, e.g. pursuing a career in science) or the community (the *economic* criterion, e.g. contributing to building a strong, science-based society). Vision II can be argued on the basis of the cultural aspect of science. Because science is a basic human endeavor, it is essential to understand its workings in order to understand oneself in a larger cultural context (the *cultural* criterion, reflecting the individual aspect) and to make informed choices for the good of modern democracy (the *democratic* criterion, reflecting the communal aspect) (Sjøberg, 2005).

In the exhibition 'The First Dinosaur' the ontological status of the represented paleontology as 'science in the making' was an attempt to engage visitors in scientific practices and knowledge production. While the relatively short duration of a standard exhibition visit might limit the potential of the exhibition to prompt changes in visitors' scientific knowledge *per se* (Vision I), the exhibition designers considered that visitors' grasp of and attitude towards scientific ways of engaging with the world (Vision II) could conceivably be influenced by the 'science in the making' ontological approach. In the following, I will investigate the potential effect of this 'science in the making' on the *scientific literacy* among visitors to the dinosaur exhibitions at Geocenter Møns Klint and Experimentarium, respectively.

## 4.2 The dinosaur exhibitions

The following sections offer descriptions of the two dinosaur exhibitions under investigation here: 'The First Dinosaur' and 'Follow the Track'. As the descriptions will show, the exhibitions had a number of similarities, but also a number of differences. I use the levels of exhibition, cluster, exhibit, and task (Achiam & Marandino, 2014; see also Chapter 3) to systematize these descriptions.

### 4.2.1 'The First Dinosaur' in Geocenter Møns Klint

'The First Dinosaur' (the subject of Chapter 2) opened in 2013 in Geocenter Møns Klint. It covers an area of about 250 square meters, and the overarching theme of the **exhibition** can be described as a journey through the scientific process of finding, excavating, preparing and analyzing the dinosaur fossils from Greenland in the creation of new paleontological knowledge. It is structured into six **clusters**: An expedition room that presents the fossil excavation setting and the involved people, a stairway area that documents the expedition procedures, an area about dinosaur posture that includes specially designed interactive treadmills, a fossil room that features paleontological objects, an environmental room that shows the plants, sediments and climate of the Triassic, and the 'climax room' which features an augmented reality experience involving the discovered *Plateosaurus* (see Chapter 2). The **exhibits** thus range from more typical museum display cases with objects to animations, video clips, hands-on interactives and augmented reality experiences.

Finally, the **tasks** of 'The First Dinosaur' involve prompts for visitors to use touch screens (manipulate 3D images of animals and play movies), read texts (on screen), interact with the special treadmills, and immerse themselves in the augmented reality. Additionally, after the addition of 'The Excavation Game' was made to the exhibition in 2016 (see Chapter 5), visitors were further prompted to play this game by excavating objects on a digital touch table and forming hypotheses on the basis of this excavation. Plateosaurus footprints on the floor guide visitors from the ground floor, through the stairway up to the third floor where the authentic fossils are presented (a lift is also available).

### 4.2.2 'Follow the Track' in Experimentarium

The temporary exhibition 'Follow the Track' opened in 2012 at the Experimentarium and was taken down in 2013. It covered an area of about 800 square meters, and its narrative follows the dinosaurs of the Cretaceous age from their lives to their extinction and subsequent excavation. Its crosscutting theme is the production of paleontological knowledge; thus, its title suggests both following the fate of the dinosaurs but also following the production of paleontological knowledge. This **exhibition** was rented by the Experimentarium from the London Natural History Museum and consisted mainly of animatronix dinosaurs (of varying quality!). It had three main clusters, including a Cretaceous area, a graveyard area, and an excavation area.

In the Cretaceous **cluster**, some of the more worn and outdated dinosaur models were partially hidden behind palisades and fences. This cluster comprised an immersive space that guided visitors through an animated ‘park’ of dinosaurs. The dinosaurs were given human voices; in their recorded monologues, the animated animal models expressed fear of an imminent disaster. The Cretaceous ‘park’ was followed by a cinematic experience that showed how the Chicxulub-meteorite (Frankel, 1999) impacted Earth, causing a mass extinction event that killed all the dinosaurs. It further shows how, in the distant future, a female paleontologist (myself!) finds and excavates their bones and ‘imagines’ what the animal might have looked like when alive. Finally, the graveyard **cluster** featured models of tombstones that mark the graves of the dinosaurs displayed in the Cretaceous cluster. It was followed by the excavation **cluster**, featuring a simulated expedition environment with shipping crates, excavation tools and an activity in which visitors can dig out little plastic fossils from prefabricated clay ‘eggs’.

The **exhibits** in all three clusters were interactive and consisted of hands-on **tasks** such as adding feathers and colors to a dinosaur, comparing the dinosaur Triceratops with a modern-day rhinoceros, and using one’s imagination to draw a dinosaur. In contrast to ‘The First Dinosaur’ at Geocenter Møns Klint, ‘science in the making’ was represented in ‘Follow the Track’ in terms of hands-on, practical procedures (e.g. the excavation) as well as the process of making informed guesses and validating them through comparisons with the anatomy of modern animals. The scientific use of the imagination is emphasized in all three clusters, aiming primarily to induce interest and motivation in very young visitors.

## 4.3 Study I: Written surveys

In the following, I describe the first part of the comparative analysis: The analysis of the written surveys which investigates visitors’ learning outcomes. These outcomes are considered in terms of changes in visitors’ scientific literacy; these changes are assessed by evaluating visitors’ scientific literacy before and after their visits to exhibitions that disseminate paleontology as ‘science in the making’. The conceptual framework for this investigation came from two studies conducted in

Western Australia with Shen's (1975) tripartite perspective of practical, civic and cultural scientific literacy as the theoretical basis. In their two studies, Rennie and Williams investigated and compared visitor perceptions of science before and after a visit to the respective exhibitions of a science center (2002) and a traditional natural history museum (2006). They developed a measuring tool in the form of a pre- and post-visit survey, with the question headings of *science*, *scientific research and the community* and *science and me*, roughly corresponding to Shen's practical, civic and cultural scientific literacy (Shen, 1975).

According to the two studies by Rennie and Williams, visitor perceptions of science were overall *less* scientifically accurate after the visit than before, both in the case of the science center and the natural history museum. This result was explained by the authors themselves with reference to the nature of science centers and natural history museums as presenters of ready-made science. Since science centers to a wide extent aim to communicate the *nature* of science in terms of concepts and universal natural laws, and natural history museums display the final *products* of science in terms of fossils, specimens, rocks, etc., the authors argue that both institutions therefore (and perhaps unwillingly or unconsciously) communicate science as something exact and universally true. With a point of departure in the explanation offered by Rennie and Williams (2002/2006), I observe that exact and universally true representations of science only feature one of Latour's (1987) two faces of science, namely that 'when things are true, they hold' (ready-made science); they exclude or ignore the other face of science, namely that 'when things hold, they start becoming true' (science in the making). My strategy in the present study was therefore to adapt the pre- and post-surveys of the Western Australian studies to see in what way the ontological status of 'science in the making' played out across the two exhibitions studied here and affected the visitor outcomes.

### 4.3.1 Method and data collection

I collected data at Experimentarium and Geocenter Møns Klint using written pre and post visit surveys and followed up the surveys with e-mails between 30 and 40 days after their visit. The sample size at Experimentarium is considerably smaller (N=15) than that of the Geocenter Møns Klint (N=67), since the Experimentarium exhibition was closed permanently before I had time to collect additional data. I have converted the data to percentages to offer easier comparisons between the two cases; however, I acknowledge that due to the different sample sizes, these comparisons may not always be robust.

***Survey questions***

The format of the surveys is based on that used by Rennie and Williams (2002/2006) in which questions relating to the theme *science* explores the visitor's relationship with the nature of science and scientific qualities, corresponding largely to Shen's *practical scientific literacy* (1975), whereas questions of the heading *science and me* relates to the opinions and emotional perceptions of science, corresponding to Shen's *civic scientific literacy* (1975). The present study, which is focused on the personal attitudes of individual visitors towards the nature of science, left out Shen's *cultural scientific literacy* (1975) component that was represented in the Rennie and Williams studies in the form of *scientific research and the community*, and was related more generally to trust in scientists and societal and ethical opinions.

Furthermore, the theme *science at the center/museum* in the Rennie and Williams studies (2002/2006) asked respondents about the everyday relevancy of the science presented at the center/museum. This theme was left out, since my studies concerned exhibitions with a narrow focus (dinosaurs and paleontology) rather than an entire science center or natural history museum that aims to present visitors with a broader spectrum of science. Some of the themes that were left out of the survey were instead targeted in the interviews (see chapter 4.4.).

As in the Rennie and Williams studies, each question item comprised a bipolar statement of two oppositely worded sentences. These sentences represented either the more or the less scientifically literate answer; in other words, following the argument of Smith and Scharmann (1999), the sentences represented scientific ideas and perceptions that were potentially more or less scientific.

Participants could choose from a seven-point Likert scale the statement they agreed most with. In the present study the first category of questions on the theme of *science* comprised five of the ten questions, and the second category on the theme of *science and me* the remaining five. The questions are presented in the following:

Question items relating to 'Science' (practical scientific literacy)

1) Only scientists need knowledge about science/Everyone needs it

2) Only scientists can understand science/Ordinary people can understand science

3) Scientists always agree with each other/Scientists often disagree with each other

4) Scientific explanations are definite/They have an element of uncertainty

5) Science has the answer to all questions/It doesn't always have the answer to questions

Question items relating to 'Science and me' (civic scientific literacy)

6) Science is interesting to me/Science is not interesting to me

7) Science is relevant to me and my life/Science is not relevant to me and my life

8) Science is difficult to understand/Science is easy to understand

9) I feel able to find information abot science topics/I dont feel able

10) I feel confident talking about scientific topics with friends/I dont feel confident

***Surveyed visitors***

At the Experimentarium, 15 sets of pre and post surveys were collected in January 2014. The 15 visitors were asked to participate upon entering the Experimentarium, and if they agreed they were asked to answer the pre-visit survey. Upon leaving the dinosaur exhibition 'Follow the Track', they were asked again to answer the post visit survey and to hand it in before leaving the Experimentarium. The pre and post visit survey forms were color-coded to indicate which sets belonged together, and visitors entered their name and personal information. The demographics of the 15 surveyed visitors are shown in Table 4.1.

At Geocenter Møns Klint, 67 visitors were surveyed in June 2015 (table 4.2.). However, this time the surveyed visitors did not answer both pre and post visit surveys. Instead, visitors were contacted at random at the entrance/exit room of the exhibition, and if they agreed, they indicated on the survey whether they were entering (pre-visit) or leaving (post-visit). This change in method was considered justified by the study's emphasis on the broader effect of the exhibition topics on exhibition visitors, rather than on individual changes. Of the 67 visitors that agreed to participate, 29 were pre-visit and 38 were post-visit.

**Table 4.1.** Demographics of surveyed visitors at Experimentarium (N=15)

| Characteristics | Category | Sample size (N) | Percent |
|---|---|---|---|
| Sex | Male | 10 | 67% |
| | Female | 5 | 33% |
| Age | 10-20 | 1 | 7% |
| | 21-30 | 0 | - |
| | 31-40 | 7 | 47% |
| | 41-50 | 4 | 27% |
| | 51-60 | 1 | 7% |
| | 61-70 | 1 | 7% |
| | 70-80 | 1 | 7% |
| Education | Primary level | 1 | 7% |
| | Secondary level | 2 | 13% |
| | Vocational education | 1 | 7% |
| | Academic education | 4 | 27% |
| | Other tertiary education | 2 | 13% |

**Table 4.2.** Demographics of surveyed visitors at Geocenter Møns Klint (N=67)

| Characteristic | Category | Sample size (N) | Percent |
|---|---|---|---|
| Sex | Male | 30 (12+17) | 44,7% |
| | Female | 37 (17+21) | 55% |
| Age | 10-20 | 4 (1+3) | 6% |
| | 21-30 | 5 (3+2) | 7% |
| | 31-40 | 38 (12+14) | 58% |
| | 41-50 | 12 (5+7) | 18% |
| | 51-60 | 2 (0+2) | 3% |
| | 61-70 | 16 (8+8) | 24% |
| | 70-80 | 2 (0+2) | 3% |
| Education | Primary level | 6 (3+3) | 9% |
| | Secondary level | 5 (2+3) | 7% |
| | Social/Health education | 10 (4+6) | 15% |
| | Vocational education | 29 (13+16) | 43% |
| | Academic education | 10 (3+7) | 15% |
| | Other tertiary education | 7 (4+3) | 10% |

***Follow-up emails***

On the survey forms, participating visitors were invited to write their e-mail address if they were interested in answering a few follow-up questions regarding long-term memories and perceptions of the exhibitions and of science. In response to this, I sent e-mails to the interested visitors a few months after their visit and received 18 responses in total.

### 4.3.2 Findings

The initial or 'first order' findings based on the written surveys directly confirm those of Rennie and Williams (2002/2006). By this, I mean that the responses to the survey items about *science* provided information about visitors' perceptions of science – or practical scientific literacy (Vision I), whereas the responses to items about *science and me* provided information about individual interests, opinions and potential willingness (or unwillingness) towards engaging with science and scientific enterprise – or civic scientific literacy (Vision II).

The responses from visitors to 'Follow the Track' followed an overall positive trend, meaning that there was a development from a lower to a higher degree of scientific literacy in visitors from the pre-visit survey to the post visit survey. This positive trend occurred mainly in the category of *science*, where responses to four of the five questions changed in a positive direction (from lower to higher degree of scientific literacy) from pre-visit to post-visit. In the five questions in the *science and me* category, two items were scored in a less scientifically literate way post visit, two were unchanged, and one item, *science is interesting for me,* showed a positive development from pre-visit to post-visit.

This somewhat positive trend did not continue at the Geocenter Møns Klint, though. As in the studies of Rennie and Williams (2002/2006), this larger survey exposed a general negative trend in the development of scientific literacy in visitors from pre-visit to post-visit responses. However, items 2, 3, 4, and 5 stood out by prompting a higher percentage of high scientific literacy answers in post visit responses and, in combination with this, either a higher percentage of low scientific literacy responses (canceling out the high literacy answers to produce a neutral trend on average), or a low percentage of low literacy responses in the post visit survey (creating a positive trend), as seen in Table 4.3.

**Table 4.3.** Pre- and post-visit results, Geocenter Møns Klint (N=67)

| Question no. | Pre-visit high literacy | Post visit high literacy | Pre-visit neutral | Post visit neutral | Pre-visit low literacy | Post visit low literacy | General Trend |
|---|---|---|---|---|---|---|---|
| 1 | 86% | 79% | 14% | 13% | 0% | 8% | Negative |
| 2 | 65% | 66% | 24% | 21% | 10% | 13% | Neutral |
| 3 | 72% | 74% | 14% | 16% | 14% | 11% | Positive |
| 4 | 76% | 79% | 14% | 8% | 10% | 13% | Neutral |
| 5 | 69% | 76% | 10% | 11% | 21% | 13% | Positive |
| 6 | 90% | 55% | 0% | 26% | 10% | 18% | Negative |
| 7 | 69% | 55% | 7% | 18% | 24% | 26% | Negative |
| 8 | 48% | 45% | 24% | 29% | 28% | 26% | Negative |
| 9 | 69% | 50% | 10% | 21% | 21% | 29% | Negative |
| 10 | 59% | 37% | 7% | 26% | 34% | 37% | Negative |

In my search for further patterns in the data, I merged the responses from the two groups of visitors to Geocenter Møns Klint into one and considered the responses to be unrelated to visitors' experiences in the exhibition 'The First Dinosaur'. These derived or 'second order' findings enhanced the pattern that was already visible in the preceding: A decrease in the degree of scientific literacy in the responses from the items concerning *practical (or vision I) scientific literacy* (items 1-5) to the items concerning *civic (or vision II) scientific literacy* (items 6-10).

In particular, the last question item about being 'confident discussing natural science with friends' scored significantly lower in average scientific literacy than other items. The same tendency was present in the Experimentarium data, since four out of the five questions that expressed a positive development were from the *science* category, while only one was from the second category *science and me*.

**Table 4.4.** Categorization test result, Geocenter Møns Klint

| Category of scientific literacy | Question no. | High literacy | Low literacy | Neutral |
|---|---|---|---|---|
| Practical | 1 | 82% | 4% | 14% |
| Practical | 2 | 66% | 12% | 22% |
| Practical | 3 | 73% | 12% | 15% |
| Practical | 4 | 78% | 12% | 10% |
| Practical | 5 | 73% | 17% | 10% |
| Civic | 6 | 70% | 15% | 15% |
| Civic | 7 | 61% | 25% | 14% |
| Civic | 8 | 46% | 27% | 27% |
| Civic | 9 | 58% | 25% | 17% |
| Civic | 10 | 46% | 36% | 18% |

With the above-mentioned ‘second order’ findings in mind, the follow-up emails were analyzed with a focus on respondents’ views on science in general *and* their self-evaluated learning outcome in relation to the observed learning outcome. I received four responses to the follow-up emails from the visitors at Experimentarium, and 14 responses from the visitors at Geocenter Møns Klint.

Regarding the observed learning outcomes, if responses to the question: ‘How do paleontologists gain new knowledge?’ included indications that new knowledge has arisen from either practical excavation or theoretical reasoning (the taglines of the exhibitions) I considered the learning outcome to be positive. I considered the learning outcome to be particularly positive if responses indicated both forms of knowledge production. Following these criteria, I observed positive learning outcomes in three out of four e-mails from Experimentarium (see Table 4.5).

**Table 4.5.** Learning outcomes in follow-up email answers at Experimentarium.

| Email | Adjectives used about science | Self-evaluated learning outcome | Observed learning outcome |
|---|---|---|---|
| 1 | Physics | None | Yes |
| 2 | Positive | Don’t know | Yes |
| 3 | Positive | - | No |
| 4 | Positive | None | Yes |

**Table 4.6.** Learning outcomes in follow-up email answers at Geocenter Møns Klint

| Email | Adjectives used about science | Self-evaluated learning outcome | Observed learning outcome |
|---|---|---|---|
| 1 | Positive | Yes | Yes |
| 2 | - | Yes | Yes |
| 3 | Positive | Yes | Yes |
| 4 | Positive | None | Yes |
| 5 | Positive | Yes | Yes |
| 6 | Positive | Yes | Yes |
| 7 | Positive | None | Yes |
| 8 | Negative | None | No |
| 9 | Positive | - | Yes |
| 10 | - | None | No |
| 11 | Positive | Yes | Yes |
| 12 | Positive | Yes | Yes |
| 13 | Positive | Yes | Yes |
| 14 | Positive | Yes | Yes |

In the follow-up e-mails from Geocenter Møns Klint, however, the observed learning outcomes were more evident, as the sample pool was correspondingly larger. Here, I observed positive learning outcomes in 12 of 14 responses (Table 4.6).

In sum, the follow-up emails expressed the same tendency as the survey data: That self-evaluated learning outcomes are found to be lower than the observed learning outcomes, and also lower than the objective feelings towards science. This reflects an interest in science, which may be expected given that the decision had been made to visit a science center, but also a low self-evaluated scientific competence, understood as the visitor's perceived ability to understand and use science on a personal basis (low civic scientific literacy). The tendency is less pronounced in the Geocenter Møns Klint answers, which expressed a self-evaluation learning outcome in more than half the replies (64%). However, this low opinion of own ability is still present, as 2 out of 14 (or 14%) express no perceived learning outcome, and 3 of 14 (or 21%) use either negative or no adjectives to describe their emotions towards science.

### 4.3.3 Discussion

In my attempt to detect a positive correlation between the representation of 'science in the making' in the two exhibitions and the learning outcomes of visitors, I find it interesting and even conspicuous how the *opposite* of the expected pattern was revealed in the first order findings (except in the smaller Experimentarium study). These results showed an apparently negative tendency (similar to the Rennie and Williams studies), where learning outcomes indicated that visitors were *less* scientifically literate after their exhibition visit than prior to it. However, when looking deeper into the data it becomes apparent that this is not the whole story. A different pattern emerged in my comparison of the second order findings with those of the Rennie and Williams studies. A closer look at the data of Rennie and Williams (2002) reveals that the negative trend they observe is especially strong in the *science* questions regarding 'science being universally true', 'science having answer to all questions' and 'scientists always agreeing with each other', which correspond to my questions 3, 4 and 5. The responses to these questions in my case conversely express a *positive* tendency. This supports the observation made by Rennie and Williams (2002) that the science center they studied influenced visitor perceptions in a direction towards science as being infallible and non-questionable; a careful extrapolation of this line of reasoning may indicate that Geocenter Møns Klint succeeded in doing the opposite, namely in disseminating science as uncertain and subject to discussion.

The Rennie and Williams findings seem to indicate that the public *expects* to find 'absolute truths' in both museums and science centers (as observed also by Hine and Medvecky, 2015) and that '[visitors] still expect the museum to present exhibits that demonstrate science's conclusiveness, rather than its doubt' as described by Conn (2011). Attempting to affect the *practical scientific literacy* of visitors may therefore prove challenging for science centers and museums; in contrast, I hypothesize that the presentation of a discipline through its practical procedures and knowledge production trajectories, like paleontology in a geocenter, is more likely to succeed in presenting (practical) scientific enterprise in an understandable form to the visitors.

The self-evaluated *civic scientific literacy* is a different story. Here, I assumed from the outset that the presentation of scientific processes in exhibitions would influence visitors' evaluation of their own capacity in a positive direction towards increased scientific literacy. However, this assumption was not supported by the data. Contrary to the *science* category, responses to the items in the *science and me* category were relatively positive in the Rennie and Williams studies - in particular, the question of 'feeling confident talking about scientific topics with friends'. Conversely at Geocenter Møns Klint this question prompted responses at the lowest level of literacy observed in the entire survey. Putting this finding together with the above-mentioned assumptions, the explanation might be that the perception of science as being fallible and questionable gives the respondents less confidence in their personal scientific knowledge, as if the realization that science is fallible causes them to question the veracity of their own knowledge.

In their discussion of 'science in the making', Hine and Medvecky (2015) claim that it offers no opportunity for the scientific knowledge to be transformed for public consumption. 'Science in the making', they claim, remains in the discussion phase amongst experts; this makes it very difficult for the public to entirely comprehend, as it has not gone through the simplification process (or didactic transposition) to become a static 'truth'. In the words of Hine and Medvecky,

> Communicating science-in-the-making therefore requires a deviation from the regular information continuum in order to temporally align the timeframe of public awareness with that of the expert (2015, page 6)

Indeed, this might be exactly the challenge I see reflected in the data from Geocenter Møns Klint. Science in the making can make visitors feel insecure about the complexity, messiness and sociality that exists in [unfinished] science (Priest, 2013), even if it is this very 'unfinished science' that provides the best examples for 'the fullness of science because science is, in fact, always unfinished' as concluded by Hine and Medvecky, 2015, page 10.

Another explanation for the low levels of civic literacy among responses could be that respondents, when asked about their perceptions of science, actually answer with respect to their perceptions of experimental science. As discussed in Chapter 2, the experimental sciences tend to be considered as ‘real science’ in public opinion. This could mean that even after a visit to a dinosaur exhibition, when visitors are asked about science in general it is plausible that they will answer with reference to disciplines such as physics and chemistry. I observed a hint of this in the very first email response from a visitor to Experimentarium: When asked about their feelings towards science, this visitor answered ‘physics’, regardless of the fact that the remaining questions were related to the exhibition about dinosaurs and paleontology. Indeed, in the Rennie and Williams study on the natural history museum (2006), a respondent answered that ‘for science, you need to go to the science center’; similarly, they detected a general tendency of natural history museum visitors not considering the displayed objects to represent ‘science’.

#### 4.3.4 Summary

On the question of how the ontological status of paleontological content as science in the making affects scientific literacy among visitors, the survey data suggests that answers that specifically target objective understanding of science - or *practical scientific literacy* (Shen, 1975), were positively influenced by the exhibition visit in both the Experimentarium and Geocenter Møns Klint. These findings are in contrast to those of Rennie and Williams (2002/2006) who studied two Australian institutions that represented ready-made science in their exhibitions. This result implies that exhibition content as science in the making *did* influence visitors’ general attitudes towards science - at least when it was presented as a (practical) journey into a tangible discipline such as paleontology. However, exhibition content as ‘science in the making’ had the opposite – and negative – effect on the subjective *civic scientific literacy*, arguably reflecting the challenges of displaying ‘unfinished’ science in all its complexity and equivocality (Hine and Medvecky, 2015).

For a more comprehensive quantitative study of visitor outcomes, a much larger dataset would naturally be needed (as in the Western Australian study by Rennie and Williams, 2002/2006). However, as a point of departure for the qualitative studies presented in the following and as a supplement to the research on the design process presented in Chapter 3, the present small-scale survey investigation nevertheless provided valuable knowledge about how the two exhibitions ‘The First Dinosaur’ and ‘Follow the Track’ were actually perceived by their users – the visitors. In the following section, I shall see if the findings of the qualitative dataset correspond to the quantitative survey data in terms of ‘science in the making’ and scientific literacy.

## 4.4 Study II: Semi-structured interviews

As was the case with the written surveys, the aim of the visitor interviews was to detect how the ontological status of paleontology as 'science in the making' in the two dinosaur exhibitions influenced the scientific literacy in visitors. However, as opposed to the survey study that used Shen's (1975) tripartite definition of scientific literacy, the interview study primarily employs the definitions of Roberts (2007), namely the Vision I and Vision II scientific literacies.

### 4.4.1 Method and data collection

Visitor interviews were conducted in both exhibitions in the form of semi-structured interviews of twelve questions, of which nine were the same in the two cases and three were adapted to the respective exhibitions. At the Experimentarium, respondents were recruited randomly at the digging activity in the expedition room towards the end of the exhibition (N=14), and at the Geocenter Møns Klint, they were recruited in advance among local families with children (N=10). The interview sample population at both institutions represented the average visitor in terms of educational level, family structure and age. This meant that at the Experimentarium, respondents had, on average, a higher level of education and were older (Experimentarium is a popular destination for grandparent-grandchildren outings), and at Geocenter Møns Klint, more traditional family structures were represented, in many cases with the mother playing the active role in planning the visit (see tables 4.1 and 4.2). Interviews were in both cases conducted with adults accompanying children, and immediately following the exhibition visit. In the findings respondents from the Experimentarium will be labeled X1 to X14, and respondents from the Geocenter Møns Klint GMK1 to GMK10.

The interview grid had questions of both practical and theoretical nature, and it was structured into four themes with each their different emphasis and aim:

<u>Theme 1: Basic paleontological knowledge (2 questions):</u> The first two questions on the grid ('what is a dinosaur in your own words?' and 'were dinosaurs successful animals?'), were mainly 'setting the stage' and testing whether some of the primary taglines of the exhibitions had been correctly perceived. These taglines included how dinosaurs evolved to become the most successful animals on Earth during the Triassic time period (in the Geocenter Møns Klint exhibition), and how dinosaurs went extinct after a giant impact event even though they had dominated the Earth

for millions of years before the catastrophe (in the Experimentarium exhibition). Moreover, the questions were designed to elucidate visitors' basic paleontological knowledge in that the nature of visitors' responses would to some extent reflect their familiarity (and thus be a gauge of their science literacy) with respect to paleontology as a discipline.

Theme 2: Science literacy, Vision I (4 questions): The next questions were targeted more directly towards practical and theoretical science literacy (vison I) of paleontology. This focus reflected how the praxis of the paleontologist was the central aspect of displaying 'science in the making'. This paleontological praxis included the documentation of excavations, analysis of fossils, formulating hypotheses and using scientific terminology. These questions included: 'what is a paleontologist?', 'how does the paleontologist gain new knowledge?', 'can you describe the work of a paleontologist?' and 'can you know anything for certain about extinct animals?'.

Theme 3: Scientific literacy, Vision II (3 questions): Following these were questions targeted towards scientific literacy (Vision II), including questions soliciting visitors' personal opinions about the relevancy and importance of paleontological research, as well as their attitudes towards the historical sciences (see section 1) in general. These questions included: 'could/would you have chosen to become a paleontologist yourself?', 'is it relevant to exhibit an expedition like this one?' and 'do you keep up with new research in natural science, like paleontology?' (only Geocenter Møns Klint) and 'which scientific disciplines are in the same category as paleontology?' (only Experimentarium).

Theme 4: Exhibition and exhibition design (1-2 questions): Then followed a few practical questions related to the physical exhibitions and visitors' experience of them. These questions were aimed at assessing to what extent the goals from the design process were fulfilled. They included: 'what do you think the exhibition aims to tell you?' 'what made the biggest impression on you and your children?' as well as one question targeted directly towards a primary exhibit in each exhibition: 'is it possible to know anything about the colors of dinosaurs?' in the Experimentarium, and: 'can you describe your experience with the excavation table' at the GMK.

All interviews were recorded and transcribed verbatim. Even though each of the questions were aimed at assessing a specific outcome or learning goal, the dataset was analyzed as a whole. In other words, the visitors' responses were pooled and subjected to deductive or 'top-down' thematic analysis (Braun & Clarke, 2007) using the four themes mentioned in the preceding. In the following, the findings are organized by the resulting categories.

### 4.4.2 Findings

The responses of the visitors to the two exhibitions 'Follow the Track' and 'The First Dinosaur' were found to fit in into three categories, relating to knowledge (elaborated in the following), corresponding roughly to the first three question themes, however, a new category emerged as well. This category included instances where visitors formulated what they perceived to be the intended learning objectives of the exhibitions (in contrast to the actual learning goals stated by the designers). This category replaced theme 4 (exhibition and exhibition design) as well as providing additional information to the category that included visitors' basic paleontological knowledge.

***'Science in the making'***

To display 'science in the making' to exhibition visitors is, by its nature, to present them with the scientific enterprise (or 'unfinished' science as defined by Hine and Medvecky, 2015). Therefore, 'science in the making' can be seen as directly targeting visitors' *science literacy* – or vision I – as defined by Roberts (2007), by presenting them with disciplinary terminology, practice and theoretical grounding.

In the collected data such Vision I outcomes were reflected in the two categories relating to content and procedural knowledge: The basic paleontological (factual) knowledge (category 1) and the methodological knowledge of practical and theoretical character (category 2).

In contrast, Vision II outcomes were understood as the derived emotional and attitudinal effects of the presentation of scientific enterprise; expressed indirectly by phrasings or terminologies reflecting either understanding, interest, insecurity, etc. towards science or the discipline of paleontology, as a consequence of visiting the exhibitions (category 2).

***Category 1: Basic paleontological (factual) knowledge***

As earlier mentioned, the overarching themes of the two exhibitions were 'origin and success of the dinosaurs - compared to other Triassic animal groups' in the GMK and 'extinction of the dinosaurs' in the Experimentarium. An important requirement for understanding either of these thematic points is a basal knowledge about the affinities of dinosaurs as a group, without which the understanding of neither its success nor its extinction makes much sense. Neither exhibition had the definition of dinosaurs as a group as their primary focus, however, the Geocenter Møns Klint (as mentioned in chapter 3), did illustrate the difference between dinosaurs and other reptiles like phytosaurs, in at least one exhibit element – the running machines. When asked about dinosaurs and their characteristics as a group, half the respondents in as well the Experimentarium as the Geocenter Møns Klint, described dinosaurs from their visual and functional affinities ‘big’, ‘green’, ‘plant eaters’, ‘carnivorous’ or ‘swimming’, rather than their biological affinities of being ‘reptiles’ or ‘extinct bird-relatives’ (the remaining half), the latter representing the more scientific response. When asked about the dinosaurs having been successful animals, the pattern of answers was likewise the same in the two institutions, 70-90% in both exhibitions answered that they considered dinosaurs to have been successful in their time, albeit the focus on their catastrophic disappearance in the Experimentarium. The basic paleontological (factual) knowledge therefore did not differ to any significant degree between the two exhibitions.

The following two categories will reveal whether the answers regarding methodological knowledge express a greater difference, and how the ontological status of the science content (‘science in the making’) had any impact on the nature of answers.

***Category 2: Science literacy - Vision 1 (practical and theoretical knowledge)***

When asked to describe the work of the paleontologist, two subcategories emerged among visitors’ responses: paleontology as primarily theoretical work and paleontology as mainly practical work. In contrast to the factual responses described in the preceding, visitors to the Experimentarium responded distinctly different to those at Geocenter Møns Klint. In particular, the distribution of visitors’ answers into the categories of either practical or theoretical work (or not knowing the answer) differed between the two groups of visitors, as illustrated in Fig. 4.7. In Geocenter Møns Klint, a larger percentage of visitors perceived paleontology to be a primarily practical endeavor than in Experimentarium, reflecting the GMK’s focus on the expedition, whereas responses at Experimentarium were divided evenly between a practical, a theoretical and a ‘not-knowing’ perception of paleontological endeavors.

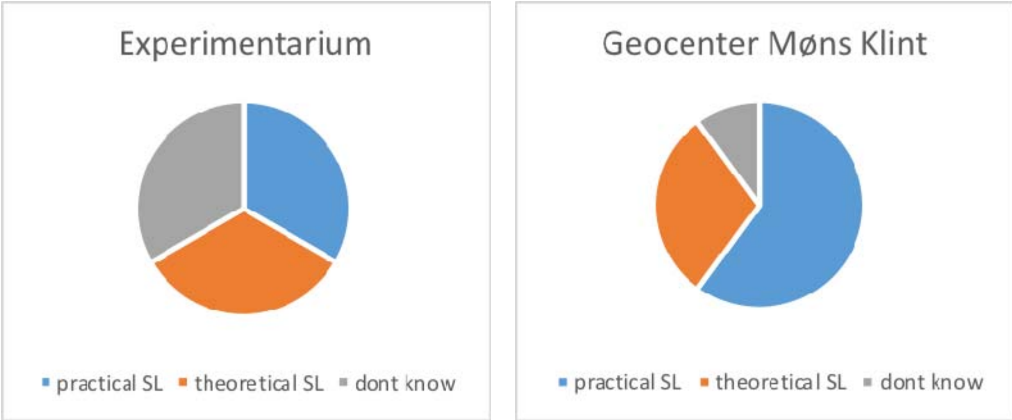


**Fig. 4.7.** Distributions of visitors' responses when asked about the work of paleontologists, in Experimentarium and Geocenter Møns Klint, respectively.

This relatively higher percentage of Experimentarium visitors 'not knowing' how the paleontologist works, compared to the Geocenter Møns Klint, is likely to reflect the dominant expedition focus of the entire exhibition 'The First Dinosaur', whereas 'Follow the Track' foci were much more dispersed across the different clusters (see section 4.2.1.), with each their different scientific topic. Moreover, the answers in this methodological category seemed to reflect the terminology and thematic foci of the respective exhibitions. In the case of the Geocenter Møns Klint pertaining to the expedition and the hypothesizing process:

GMK1: It is about, uh, collecting evidence, and finding out what happened [in the past] […] that is also what the Geocenter is good for, the kids can explore different time periods, like little detectives, and at the same time follow the pictures […]

Experimentarium answers being instead targeted towards the use of extant animals for comparative analysis, guessing and using your imagination, reflecting the foci of the first exhibit clusters of 'Follow the Track':

X7: It illustrates very nicely that you believe a lot of things […] because the head of the dinosaur was like a crocodile and the body was like a bear. Then you can presume that it was upright, but might have eaten fish. A nice way to display how we have come to the conclusions we have – but also how nothing is certain – it might also have been swimming around.

***Category 3: Science literacy - Vision II (attitudinal)***

In contrast to *science literacy*, *scientific literacy* (or Vison II by Roberts, 2007), is measured here as the attitudinal or emotional responses that reflect the indirect and derived effects of the presentation of paleontological enterprise ('science in the making') discussed in the preceding.

Visitors' responses were found to fall into a larger category in which visitors expressed that paleontology was too difficult or a poor fit for them although they found it interesting, and a second, smaller category in which visitors found the adventure of the job enviable or at least attractive. The first category contained 50-70 percent of the answers in the two exhibitions, and many visitors explained that paleontological work would require too much patience for them, and an unattainable level of scholarly knowledge.

> GMK8: Well, I think you would have to be very smart, right. Well, like familiarize yourself with stuff, read a lot of stuff, create knowledge, devise stuff – and be able to sit still; [but the digging part] that, I would love.

> GMK9: I think it is a touch job, right. Even if they make it look easy, I don't think it is. But exciting. […] Digging and finding bones, it must take hours. A long time.

However, visitor responses that addressed the relevance of disseminating the scientific process of a discipline like paleontology (these responses occurred mainly in Geocenter Møns Klint) indicated that an enthusiasm *had* been awoken in many of the respondents.

Even the respondents who previously described paleontology as too difficult or unfit, expressed an interest in learning about the process of finding fossil evidence. However, these respondents' frequent use of linguistic hedges[3] like 'actually' and 'quite' might reflect a need to explain or defend this interest – or to soften the contradiction between the 'established' consideration of

[3] A linguistic hedge is a mitigating word, sound or construction used to lessen the impact of an utterance due to constraints on the interaction between the speaker and its listener, such as politeness, softening a controversial statement or avoiding the appearance of bragging, etc. (Mira, 2010)

paleontology being an irrelevant discipline (see Chapter 2) and their own feeling of interest and relevancy.

GMK5: Actually, I think the expedition is interesting too […] to hear the enthusiasm from those who have been out experiencing it.

GMK7: Actually, I think it is fun to see the screens with real people on the expedition. It allows you to relate to it, and whether there are situations, you could imagine being part of yourself.

GMK9: I think that's quite fine. It tells you something about the workload. It is not just taking a vacation in Greenland. It takes a lot of work and time. And for the children to understand that it not just something that comes in a van.

In the Experimentarium the scientific process is also described by visitors as relevant, but in a more philosophical way that reflects the speculative theme of the exhibition. Note that the following answer parallels that of question item 4 of the survey analysis, even if the respondent was not familiar with the surveys, as interview respondents and survey respondents were not the same in the Experimentarium.

X7: That is important for our general view of the world [to know that scientific knowledge is subject to constant reevaluation and possible change]. If we walk around presuming what we know is 'the truth', then we are talking religion. It is important to realize that we are not talking about universal truths.

***Category 4: Self-evaluated (versus intended) learning goals***

The last category of answers in the dataset concern the visitor outcomes as experienced by the respondents themselves. Their answers relate either to the exhibition as a whole, to specific exhibits, or to outcomes of a more philosophical or holistic nature. A few answers moreover reflect the respective institutional pedagogies of Experimentarium as a science center, and of Geocenter Møns Klint as a hybrid institution (see Chapter 2). These responses pointed to interactivity (in the case of Experimentarium) and a mix of interactivity and authentic objects (in the case of Geocenter Møns Klint):

X1: Meant in the best way it is a very active kind of museum. Not (…) a dry museum with pictures, where you are just walking through, looking at pictures.

GMK6: It is nice to see the original material as well, because […] that's where you go quiet […] that's your emotions talking to you in a completely different way. So I think modern exhibitions without soul are entertaining and all that. But you need that feeling that makes you silent, and for that you need original animals – and to be allowed to touch [the footprints] is of course just fantastic.

Other answers reflected visitors' general acknowledgement of the respective institutions as providers of general education or *Bildung*:

X3: You can say it is a kind of 'general education', becoming a bit familiarized with the ancient past.

GMK3: Well, [the important outcome is] to become more knowledgeable – always to continue learning and to expand your horizon. Especially for the kids. We, adults, can also be fascinated, but I think especially for the kids.

This acknowledgement was moreover present among visitors to both exhibitions in a larger and more personal perspective:

GMK4: It gave me a kind of consciousness about life having been here so much longer than we have, and that we have to look after it, and study it – so that we can know what it is we have, and value it.

GMK6: This exhibition gave me a feeling of joy of doing science, of excavating and a joy of learning – and of knowledge in general. That is the feeling I take with me. Not as something being foisted on me, but as the holistic experience.

Finally, visitors' responses also touched upon the importance of inspiring motivation in the future generation of potential paleontologists – as well as the realization of paleontology being a 'real' science, as exemplified here (again softened by a multiple linguistic hedges):

> X14: I think it gave my boy an experience of the 'dinosaur-thing' actually being a job possibility. That you can actually work with this kind of knowledge – as a grown-up – and not just, you know, collect toys as a kid. That it is a possibility and actually a real science.

### 4.4.3 Discussion

The results of the qualitative comparative study of 'The First Dinosaur' and 'Follow the Track' showed that visitors responded to the two exhibitions in terms of both *science literacy* and *scientific literacy*. In the following, I discuss how the two visions of scientific literacy play out across the two exhibitions at the Experimentarium and the Geocenter Møns Klint, respectively. Furthermore, I discuss the self-evaluated learning outcomes of visitors with the outcomes intended by the exhibition designers.

***Vision I***

There is a consensus in museum education research that learning can no longer be understood as it was in early studies: As direct transmission of knowledge from a teacher or disseminator to a receiver (cf. Mortensen and Quistgaard, 2011; Falk and Dierking, 2000; Hein, 1998). Today, the constructivist learning paradigm conceives of learning as the active, contextual construction of knowledge by the learner, built on the knowledge structures the learner already has (Anderson & Ellenbogen, 2014). For this reason, I find it likely that knowledge in the form of general facts such as the tag lines and text information of the two dinosaur exhibitions is not likely to be acquired directly by visitors; rather, they might acquire it indirectly in the form of Vision II outcomes as discussed previously. The visitors' responses concerning basic paleontological knowledge in present study lend support to this interpretation by not reflecting particular learning outcomes with respect to factual dinosaur knowledge. To the contrary, the nature of these answers was found to be similar in the two exhibitions, despite their different and almost opposing tag lines, for instance about the success ('The first dinosaur') contra the extinction ('Follow the track') of dinosaurs.

The fact that a majority (up to 90%) of respondents in both exhibitions gave the correct scientific answer of dinosaurs having been successful animals (even though Experimentarium's 'Follow the Track' focuses on their catastrophic extinction) is thus not likely to be prompted by the respective exhibition visits; perhaps this response rather reflects a paradigm shift in the understanding of dinosaurs described as 'the dinosaur renaissance' (Bakker, 1975). This renaissance has shifted the academic perception of dinosaurs towards their having been active and endothermic relatives of birds rather than the slow, ectothermic reptiles they were believed to be in previous decades. This paradigm shift has arguably become public knowledge in recent years, due to an extensive coverage in written tabloids as well as television shows and movies. It is therefore likely to be reflected in the answers from visitors that concern dinosaur success. Similarly, the 50/50 ratio of respondents describing the animal group non-scientifically (by function) contra scientifically (by genus), is more likely to reflect the respondents' level of interest or education concerning natural science (familiarization with terminology, phylogeny, etc.), than a factual understanding received in the exhibition. The questions concerning basic paleontological knowledge can therefore be considered as an indication of respondents' level of prior knowledge (level 0 in the levels of co-determination, fig. 3.3), rather than as a measure of learning outcome. As such, they point towards a somewhat homogeneous level of prior Vision I literacy among visitors to the two institutions, even if the demographics (tables 4.1 and 4.2) suggest general educational levels to be slightly higher among visitors to the Experimentarium.

In contrast, the answers concerning the work of paleontologists showed significant differences between Geocenter Møns Klint and Experimentarium as illustrated in fig. 4.7. In Geocenter Møns Klint the overarching focus on the expedition and the practical work related to excavations was expressed in the high percentage of answers explaining the work of the paleontologist in practical terms, relating it to excavation work. Even though the interviews with visitors to Experimentarium were conducted in the middle of a digging activity, excavation was not the primary focus of 'Follow the Track', and significantly fewer visitors responded that 'excavation' was a primary way for paleontologists to gain new knowledge. Instead, one third of Experimentarium respondents explained the work of the paleontologist to be theoretical in nature, corresponding to certain themes of 'Follow the Track'. Another third of the respondents responded that they did not know.

This higher level of insecurity could indicate that many visitors had not noticed – or understood – the exhibition's attempts to illustrate the work of paleontologists.

In sum, the data suggest that 'science in the making' was perceived differently in the Experimentarium than at Geocenter Møns Klint, and that it was more successfully taken up by visitors at Geocenter Møns Klint. This assessment is supported by the fact that almost all respondents at Geocenter Møns Klint could account for aspects of paleontological work, although paleontology seemed to be more diversely understood at the Experimentarium (where more different aspects of paleontology were accounted for, even if only a minority of respondents were able to do so).

***Vision II***

Regarding the attitudinal and emotional responses towards paleontology as a discipline, data from the two exhibitions somewhat contradicted itself. Across Experimentarium and Geocenter Møns Klint, 70-80% of respondents felt that paleontological work was a poor fit for them. However, many considered paleontology as a relevant subject for dissemination, and a majority of respondents expressed a high degree of interest – even to some extent surprising to themselves, as demonstrated by the remarks cited on pages 106 and 107. The ways in which the relevance of paleontology was expressed in the visitors' responses included both *individual* arguments that emphasized understanding the context and origin of the displayed knowledge, and *communal* arguments that emphasized acknowledging the work and workload of scientists in the collection of fossils. As discussed by Sjöberg (2005), such arguments correspond primarily to the *cultural* criterion, the importance of which lies in the fact that learners should understand themselves within the larger cultural context of the scientific enterprise and creation of knowledge.

Vision II-related outcomes observed in the written survey analysis (Section 4.3.2) showed levels of *practical* and *civic* scientific literacies to be higher than the self-evaluated levels. Certain patterns in the present interview data suggest a similar tendency in visitors' *cultural* literacy. Many visitors used phrasings that reflected uncertainty towards discussing scientific content (e.g. answering questions with a question or using the Danish 'dialogue particle' of insecurity 'vel'), which may be an indication of a relatively lower level of *self-evaluated* scientific literacy, compared to the higher levels of scientific literacy *observed* in their answers (for instance the demonstration of disciplinary understanding of paleontology).

***Self-evaluated contra intended learning goals***

As a continuation of the design process and the intended (learning) outcomes that were formulated by the design team (described in Chapter 3), it is interesting to note that visitors' responses followed roughly the same categories as those described by the designers. Nadia Rosendal Nielsen described these intended learning outcomes in the following way (Section 3.4):

> It was a balance between disseminating certain scientific procedures – we wanted to present how paleontologists work, but also the 'adventure' connected to that procedure. And at the same time [we wanted to] get some scientific points through in an 'edible' way for people to understand.

The visitor data indicates that the presentation of both paleontological practice and the representation of paleontological 'adventure' *was* successful. Most visitors expressed both interest and enthusiasm in relation to the expedition to Greenland, albeit - with a few exceptions - not to the degree that they wanted to follow the adventure themselves. Even so, the understanding of the science of paleontology that resulted from the visit seems to have evoked feelings like appreciation of research on one hand, but also of the philosophical outcomes of research on the other. Philosophical outcomes include the understanding of deep time and the place of human beings in the big picture of time and evolution (as expressed by the quotes on page 106 and 107), in addition to general acknowledgement of the value of *Bildung*, as expressed by several respondents (page 106). These holistic outcomes may conceivably be indicators of longer term influences on attitude and opinions of paleontology (and science) among the visitors after the visit.

At the Experimentarium, the intended learning outcomes from the design process were not studied. However, the expectations of visitors were addressed by one of the interview questions, in which 50% of Experimentarium visitors answered that purpose of their visit was 'entertainment', whereas the remaining half answered either 'learning' or 'entertainment *and* learning' (this question was only discussed in the Experimentarium, since Geocenter Møns Klint visitors were recruited in advance). This pattern corresponds to the typical expectations of visitors to a traditional science center in which learning is a part of the visit, but not the primary purpose.

Hine and Medvecky (2016) call this strategy ‘edutainment’, and they find it to be critical for exhibition learning outcomes, as illustrated in the following quote:

> The emphasis on entertainment has had a number of far-reaching consequences on the educational mission of science museums. It has limited the accessibility of the science museum for adults, and has simultaneously restricted the degree to which complex discussions around scientific topics can be presented (page 3).

The entertainment strategy has nonetheless been employed since the birth of the original science center (Exploratorium in San Francisco, 1969), for the very reason of enhancing motivation and interest of learning, by offering a learning site of a ‘fun’ and voluntary nature (Falk, 2006).

In another perspective, Pekarik (2010) questions the idea of measuring outcomes altogether because visitors come to exhibitions for their own reasons. This means that they may resist – or even resent – being taught something that has been predetermined by the exhibition designers. Pekarik thus describes the ‘outcome-based design’ as a simplistic method for evaluating these pre-determined learning outcomes; instead, he encourages a more qualitative method of analyzing the individual visitor experience and its complex interaction with the visitors’ prior knowledge and experiences (designated as level 0 in Achiam and Marandino’s (2014) levels of co-determination).

In the presented data here, the findings that concern factual knowledge (Vision I) align with Pekarik’s (2010) critique, whereas the indications of more emotional and personal outcomes among visitors suggests that *some* outcomes are indeed feasible and thus worth including as learning goals when designing ‘science in the making’ exhibitions. Even if these outcomes belong to the Vision II category, I interpret them as effects derived from the dissemination of science (factual Vision I) or ‘science in the making’ (practical/theoretical Vision I) in the exhibitions, and as such, these outcomes should not be considered as separate entities of evaluation or dismissed as ‘learning outcomes’ in their own right.

***Methodological considerations***

A qualitative study with semi-structured interviews like the one presented here of course has potential methodological implications. It uses an interpretative approach (Treagust, Duit & Won, 2014) to understand the qualitative data, and as such does not aim to claim objectivity in a positivist sense. Rather, it attempts to make sense of the different layers of the interview data, including the personal opinions, language-use of the respondents and the context in which the data were produced. This provides the study with more robustness when it comes to comparing outcomes across different contexts even though conditions in these contexts (the exhibitions) were not identical. However, the fact that the respondents in Geocenter Møns Klint were recruited in advance and that they were subjected to screens in the exhibition displaying the interviewer (myself) as one of the expedition team members is likely to have motivated them into a higher degree of enthusiasm than their – randomly consulted – Experimentarium counterparts. Second, the nature of the outcomes in any investigation of this character is unavoidably influenced by the values of expectations of the researcher (me), since I – as during the design process of the exhibition – was potentially subjected to the same conditions and constraints in the development of my interview grid as in the design process itself. However, in triangulation with the more positivist written survey analysis (section 3.3.), I consider the combined data of interviews and surveys as validly comparative material, and in the following I support this comparison with a study of a particular exhibit at the Geocenter Møns Klint in which I carried out visitor observations.

## 4.5 Study III: Observations

Following the dinosaur expedition in 2012, and the opening of the exhibition 'The First Dinosaur' in 2013, a second expedition was carried out in 2016 (see background story in chapter 3). An interactive excavation table had been a planned element in the original exhibition design; it had however been dismissed for economic reasons. With the new scientific discoveries that were made in 2016, including several phytosaurs as well as a 'smoking gun'[4], the idea of the interactive excavation table was reintroduced and subsequently integrated into a new exhibition element, with the additional purpose of refreshing the original exhibition.

This time, the excavation activity was designed as a combination of a digital simulation of the physical excavation situation in Greenland (which involves digitally removing sediment layer by

[4] The smoking gun is defined as the determinative piece of evidence for one of the hypotheses in the multi-hypotheses methodology of natural history (see Chapter 2), after which the concerned hypothesis changes into the established theory to explain the event.

layer in search for fossils) with the abstract theorization process carried out by the scientists in the field (which involves hypothesizing and finding the ‘smoking gun’). The Copenhagen-based company *Kongo interactive* carried out the digital solutions of the table, while Geocenter Møns Klint staff, myself included, developed the scientific content.

### 4.5.1 The excavation game

The excavation game is a multiplayer experience in which 1-8 players can digitally dig out fossils, moving sediment layer by layer, as in an authentic setting. A built-in narrator introduces the players to the three hypotheses (that represent the original hypotheses of the paleontologists) of why several phytosaurs of different sizes and ages were found in the same location. These hypotheses include:

1) That the phytosaurs had exhibited social behavior, thus allowing for a family group to be collectively surprised by a mudslide.
2) That a prey animal had been trapped in a pool of mud, thereby attracting several predators (phytosaurs) who then also became trapped in the mud.
3) That the location represented the last watering hole during a drought, thereby attracting all the animals in the area in their search for water, but ultimately drying out leaving these animals to die of thirst.

The game proceeds as the players gradually remove layers of sediment by touching the digital surface of the table (indicated by sound and visuals of dust). In this process, the players uncover a number of fossils similar to those actually found in the real excavation. The narrator each time explains how the new finding fits into the participants’ selected hypothesis; on the basis of this fit, the participants may change their choice of hypotheses or remain with their chosen one (see http://kongo.dk/project/the-excavation-game/).

One of the last findings – in the game as well as in the real excavation - is the bottom layer of sediment, which is of substantially older age than the others, but of similar geological composition – indicating that the event that killed the phytosaurs was a repetitive event. This similar bottom layer and the nature of some of the other findings, in particular an articulated fish, is convincing evidence of the location having not only been the last watering hole at the time of the Phytosaurs’ death, but of having been so a number of times, probably each time a severe drought stroke the area. The older layer of sediment (in combination with the fish) thus represent the 'smoking gun' in this case; and players therefore have the opportunity to find this 'smoking gun' and hypothesize in much the same manner as the original scientists.

The concept of the 'smoking gun' is presented as text next to the table, and by the narrator *when* or *if* the bottom layer is found. Rather than being a competition between players, the excavation game is a task of cooperation and systematic reasoning, aiming to solve a scientific question. Since the game is time limited, however, the players need to remove sediment quickly enough that they can find sufficient numbers of fossils within the game's time limit.

**Fig. 4.8.** The Excavation Game

### 4.5.2 Method and data collection

While recruiting families for interviews described in section 3.4.1, I also asked the families if they would participate in a test and observation analysis of the new excavation game. All of them agreed to do so, and the following analysis therefore contains 10 observations of families (from 2-6 participants), with a minimum of one adult and one child. The age of the children ranged from 1½ to 15 years.

The families were observed and video recorded while playing the game one or several times. They were given an introduction, which was kept very brief since the table introduces the game quite elaborately by itself. Otherwise, I interacted minimally with them. The only exceptions to this were in cases where I helped out if a small child wanted to enter or leave the game, or when I answered short clarification questions of a more practical character. However, the camera (a Huawei P9 smartphone) was hand-held by me with the potential implications that might have had for participants' behavior.

***Intended learning outcomes***

Two categories of learning goals guided the design of the excavation table. The first category concerned the practical skills of paleontological excavation, and the second concerned the theoretical reasoning of the paleontologist, using fossil evidence to either validate or reject the selected hypotheses. For obvious reasons the activity of excavating in the digital game is not an authentic experience in the sense of moving heavy, tangible rocks, but instead an experience of how fossils (and sediments) are deposited in layers. Thus, the participants experience the need to remove upper layers (that might contain fossils) to reach lower layers (that might contain other – often older – fossils). This experience of how rock layers reflect a certain time sequence refers to Steno's original law of superposition (Steno,1669/1671), which was the foundation of the discipline of stratigraphy as well as the realization that the Earth was older than described in the Bible. Even though this kind of existential realization probably not occurs in the average player, it is possible that the mere experience of fossils being found in different layers, prompts realizations concerning sedimentation process and time. My strategy to detect such experiences in the observations of the participants was to listen to their shared conversations concerning the layers while I observed their physical interaction with the table.

The second, more important goal of introducing players to the scientific theorization process was directly linked to the analysis of the educational significance of paleontology (section 2); more specifically to the multi-hypothesis and retrodictive methodology of natural history. In the excavation table, these features were described metaphorically as the methodology of a criminal detective, and embodied using the findings. The finding of an articulated fish as evidence for the past existence of a watering hole, and a sequence of similar layers as evidence of a sequence of similar events to conclude how several animals of the same species died in one location (the smoking gun). Again, conversation concerning their choice and change of hypothesis was the main source of evidence with respect to the development of this methodological awareness among participants.

### 4.5.3 Findings

Participating families fell into two distinct categories, with a few families displaying combined characteristics of the two. These two categories consisted the *careful* and the *fast* diggers, respectively. The careful diggers were slow to begin, starting out very gently by touching the table (digging) one finger at the time, moving slowly ahead, and only later realizing that the game was on time (this is not specified in the introductory speak, but implied by a timer in the lower corner of the screen). Those families often discussed the hypothesis they had chosen and the fossils they had found, and characteristically at some point during either first or second game, mastered the technique, and began working faster and more efficiently. In contrast, the fast diggers included families who excavated very fast from the outset. They were often the families with children aged nine to eleven who were very enthusiastic about digging and finding fossils. In many cases, the fast diggers did not seem to reflect very much on their choice of hypothesis or the explanatory speaks from the game; rather, they discussed how much time was left, and who found the most fossils. However, there were some deviations from this pattern.

The learning outcomes observed among the participating families reflected their different digging and thinking strategies. I observed discussions of the nature of the sediment layers among three of ten families, two of which were fast diggers. In all three cases, the sediment layers started out as a source of irritation, but the families later realized how these layers were a technical necessity to reach the fossils as well as a factor of excitement. In the following, I offer some examples:

> **Family, in subsequent interview**
>
> Jenni: They [fossils] lie in different layers, right, and you know – kids, they just 'dig in'. But, yeah, you need to do it a few times, in order to really grasp it. That is not a bad thing, though.
>
> Interviewer: No?
>
> Jenni: No, it becomes a competition – to reach the lower layers first, and the first time you don't really nail it, but the second time you get deeper.
>
> **Family 6 (during the game)**
>
> Birka: It is a long way down.
>
> August (12 years): Yeah, but it is about removing the old stones to get to the new ones, actually. [After the game August expresses how he initially felt it annoying to have to remove the layers to reach the fossils.]

Discussions on the choice of hypothesis, on the other hand, were observed in seven out of ten families. Only one slow digger family did not vocalize any reflections about their hypothesis or the sediment layers, while seven out of ten families made the final choice of the correct hypothesis. Two families managed to reflect on both their choice of hypothesis and the characteristics of the layers, although reaching the correct conclusion only in their second or third game (due to a slow start). One family never managed the right conclusion; nor did they engage in any discussion. This family did also start out slowly, but possibly from other reasons than other careful diggers (see graphic overview). I here provide a few examples of vocalized hypothesizing processes in players during the game:

**Family 6**

Birka [reads aloud from the textbox that pops up as they find the bottom layer]: A mudslide hardly occurs on the same spot twice [She turns to her family] but I guess a watering hole could appear the same place twice, right, then new water would flow it, and…

August (12 years): Yeah, if it is the right place, that could be.

Birka: Should we change?. [They change their hypothesis to the last watering hole.]

**Family 2**

Kim: I think it is this one (points to the watering hole). I can’t be sure it is not a mud trap, of course, but there is fish and water animals and stuff

In the following, a graphic overview (fig. 4.9.) is provided to illustrate the correlation of digging strategy and observed learning outcome in the form of either winning the game or actively reflecting about either the choice of hypothesis (hypothesizing) or the nature of layers (superposition).

| Family | Category | Correct hypothesis | Verbal reflection on choice of hypothesis | Verbal reflection on layers |
|---|---|---|---|---|
| 1 | Mixed | X | X | X |
| 2 | Fast digger | X | X | - |
| 3 | Fast digger | X | - | - |
| 4 | Fast digger | X | X | - |
| 5 | Slow starter | - | X | - |
| 6 | Slow starter | X | X | X |
| 7 | Fast digger | - | - | X |
| 8 | Slow starter | X | X | - |
| 9 | Mixed | X | X | - |
| 10 | Slow starter | - | - | - |

**Fig. 4.9.** Graphic overview of findings

***Self-evaluated learning outcomes***

Immediately following the completion of each game, I asked about the family's experiences interacting with the game and later, during the interviews for the comparative analysis, I targeted one question towards the excavation game. In those follow-up comments, most families addressed the experience with adjectives such as 'exciting', 'fun', 'interesting' and 'captivating', but engaging in an activity together was also mentioned among four out of ten families, pointing to how the activity involved cooperation and that all age groups could participate.

Three families described the technical qualities of the table as 'modern', whereas two families found it 'difficult' or 'advanced'. Some reflection on the characteristics of sediment layers was also present among responses to the follow up questions, whereas no families mentioned the process of hypothesizing or constructing theoretical explanations. This might imply that learning outcomes regarding this particular kind of (Vision II) scientific literacy happens without the learner being aware of it, and that measuring such outcomes may require subtler techniques in order to capture indirect or tacit changes in the theoretical understanding. I shall discuss this further in the following.

### 4.5.4 Discussion

In contrast to the surveys and the interviews that were part of the comparative analysis, the observations of families interacting with the excavation table were only conducted at the Geocenter Møns Klint. Furthermore, while 'science in the making' in the comparative analysis was represented in the form of visual or written representations of paleontological work, in the excavation table it was presented to the visitors in the form of an inquiry-based activity.

Accomplishing the practical task of excavating fossils as well as the theoretical task of using these fossils to choose a valid hypothesis was used in the present study as an indication of a *science literacy* (Vision I) outcome – and to a derived extent a *scientific literacy* (Vision II) outcome. These outcomes were observed as either 'winning the game' (by choosing the right conclusion), or as verbal discussions of the choice of hypothesis (i.e. expressing a process of hypothesizing) during the game. It is of course not possible, from recordings such as these, to know what kind of internal discussion might take place in the minds of the player; however, the data *do* indicate that the families who did not engage in discussions also didn't succeed in drawing the correct conclusions. The data shows that seven out of ten families eventually 'won the game' by selecting the correct hypothesis – the watering hole – and out of these seven families only one did not verbally discuss their reasonings while playing. Of course in real science there is no such thing as 'winning the game', and one can never be absolutely certain that even an established theory will continue to hold, as is illustrated by the occasional paradigm shifts (see section 1). However, in paleontology, the 'smoking guns' are part of the so-called *parsimonious* thinking within the methodology of natural history: to choose the hypothesis most likely to be correct, by use of the smallest possible number of assumptions.

Of the three families who failed to select the correct hypothesis, one *did* discuss the reasons for selecting their hypothesis, whereas the remaining two neither engaged in discussion nor succeeded in concluding that the water hole was the correct hypothesis. The latter two families may be assumed to not have achieved any learning outcome with respect to hypothesizing, but they might still implicitly have understood practical features of the work of paleontologists. Indeed, one of these families did talk about the characteristics of layers, even if they did not discuss the hypotheses (see fig. 4.9.)

I was not able to detect any significant difference between the two categories of 'careful diggers' or 'fast diggers' in relation to drawing the correct conclusion. Both groups succeed equally well in 'winning' the game (excluding family 10 who did not engage in any discussion and possibly did not understand the basic purpose of the game), and their different strategies are likely to reflect basic human differences in dealing with tasks, rather than competences in dealing with science. The psychological reasons behind such strategies are beyond the scope of this study, however, data indicate that 'fast diggers' had their emphasis on the digging activity (since they reflected more about the layers), relative to 'careful diggers', who seemingly had their emphasis mainly on the reflection and hypothesizing process.

It would be tempting to categorize the two groups into a more practically oriented group (the fast diggers) and a more theoretically oriented group (the careful diggers). However, the composition of families reveals that fast diggers more often were families with children of the age 8-12 years, rather than the families with very small children. Instead of suggesting that the 8-12 year olds had a better practical approach to task-solving in general (even though that might also be true), subsequent interviews indicated that familiarization with computer games and interactive touchscreens (iPads, etc.), instead could account for their rapid familiarization with the game of the excavation table. This is illustrated by the following quote:

> GMK4: Very modern presentation of very old stuff. It gives [fossils] new life for computer-people. Like my son, if he doesn't play football, he plays computer games. And even the little one. You could see how much the iPad means. He knew that when something turned up, he had to push.

As discussed, the participants did not mention the theorization process as part of their experience. However, even if learning outcomes cannot be measured directly in an observation study such as the present, it is evident from the success rate of the visitors interacting with the table that some sort of tacit learning outcome does occur when families use the scientific methods of paleontology to solve a task in a game.

The process of embodying a disciplinary methodology (such as the paleontological method in the excavation table) into an inquiry-based activity is discussed in further detail in Chapter 5 (page 128-130). Here, I also further discuss the theoretical foundations of such inquiry-based learning.

## 4.6 Triangulation summary

Findings in the data triangulation suggest that 'science in the making' as an ontological strategy has the potential to influence – to some extent – visitors' *science* literacy (Vision I, Roberts, 2007) with respect to as well factual, practical and theoretical knowledge. But, to a larger extend to influence visitors' *scientific* literacy (Vision II; Roberts, 2007), as all three visitor studies detect learning outcomes belonging to this category (see fig. 4.10).

The observation study of the excavation game, moreover implies that an inquiry-based exhibit element (level 2 by Achiam and Marandino, 2014), to a higher degree succeeds in generating learning outcomes of both Vision I and Vision II, than the exhibitions in their entirety (level 4 by Achiam and Marandino, 2014), as illustrated in the last column of fig. 4.10.

**Fig. 4.10**. Triangulation outcomes of Vision I/II and self-evaluated learning

| **Learning outcome** | **Survey (exhibition level)** | **Interview (exhibition level)** | **Observation (exhibit level)** |
|---|---|---|---|
| Vision I | | | |
| - factual | / | - | +[5] |
| - practical | / | +/- | + |
| - theoretical | / | +/- | + |
| Vision II | | | |
| - detected | + | + | + |
| - self-evaluated | - | - | - |

The most notable pattern across all three investigations, however, is the difference between the observed and the self-evaluated learning outcome in visitors, in which visitors consistently reported a lower degree of scientific competency than that reflected in the observed outcomes.

[5] Factual knowledge here accounts for learning the fact that the phytosaurs died at the last watering hole. A knowledge necessary to 'win the game'.

A level of general uncertainty (and perhaps modesty) was found among visitors across the survey, interview and observation data. Even in the e-mail data that resulted from the investigation of long term outcomes, the self-evaluated literacy is lower than the observed literacy (see fig. 4.5 and fig. 4.6.). This suggests that there is an overall dichotomy between visitors' interest (measured to be high) and their self-evaluated competence, as well as between the detected outcome and the self-evaluated outcome. The *a priori* analysis of paleontology reported in chapter 2 described the societal trend of experimental sciences being regarded as 'more scientific' than the historical sciences such as natural history and paleontology. This phenomenon is likely to be part of the explanation that visitors find science (i.e. experimental science) in general to be difficult; I hypothesize that they then project this general attitude onto even the scientific subjects they find to be 'more interesting' as well as easier to comprehend.

Although these subjects are in the present case dinosaurs and paleontological excavations, the distinction between experimental and historical sciences is likely not even to be recognized by the visitors, because natural history is not, at the moment, comprehensively taught in the established educational system in Denmark, as was concluded in the *a priori* analysis (section 2.2.).

In other words, the present study lends further weight to the argument that natural history should be reintroduced into general science education as suggested in section 1. Since a low level of self-confidence arguably influences scientific capacity (*science literacy* as well as *scientific literacy*), it is likely that this level could be enhanced with the broader realization or even acknowledgement that science is an array of different methodologies as well as an array of different styles of reasoning (Kind and Osborne, 2017). This acknowledgement could allow more people to feel confident in science, giving them the possibility to involve themselves into the particular 'style' of methods best suited to them on an individual basis. One might argue, though, that the exhibition format provides exactly this broader perspectivation of science. Even if the learning outcomes are not necessarily noted or recognized by visitors themselves, it is evident from the present data triangulation that it *does* exist, and that the derived effects of presenting 'science in the making' include enhancing the scientific literacy of Vision II, by Roberts, 2007.

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# Chapter 5
# A practical evidence-based design model

In this last section of the dissertation, I first provide a summary of the institutional influences on the dissemination of ‘science in the making’. I then outline the development of a practical design model based on the empirical material I have collected that addresses this issue. This empirical material includes the practical development of one of the exhibition elements, which is investigated in the following: The Excavation Table. My status as an industrial PhD had focused my attention on the problems of practice and encouraged or prompted me to develop this design model in a very practice-oriented way. The model therefore is anchored in the concrete, hands-on exhibition design processes I have gained experience with, but has special emphasis on implementing the ontological status of a scientific discipline as ‘science in the making’. This discipline is, of course, paleontology in the present case. Accordingly, my hopes and expectations are for the resulting model to be used as a tool for future exhibition design processes, as well as a descriptive tool to recognize steps and decisions in such a design process.

## 5.1 Institutional influences on ‘science in the making’

As is evident from Chapter 3, which triangulated and discussed the results of the visitor studies in both Experimentarium and Geocenter Møns Klint, the ontological status of science as ‘in the making’ can, when embodied in exhibition design, have an influence on the scientific literacy among visitors (understood as Vision I and/or Vision II by Roberts, 2007). Chapter 3 additionally illustrates some differences in the implementation strategies of the discipline of paleontology into the exhibition design. For example the strategy of presenting visitors in Geocenter Møns Klint with the documentation of scientific praxis of an authentic excavation, or the Experimentarium inviting people into a very non-authentic environment of talking animatronix dinosaurs, prompting visitors to employ their imagination and requiring them to suspend their disbelief.

Traditionally, science *museums* (e.g. of natural history or science and technology) take a pedagogical approach which is based on the objects and their related disciplines (Conn, 1998, 2010). This approach often corresponds to the inductive way of producing scientific knowledge as discussed in Chapter 2 (see also King & Achiam, 2016). In contrast, science *centers* typically employ a more process-oriented or experimental approach embodied in their characteristic discovery pedagogy (Ogawa, Loomis & Crain, 2009), as discussed in Chapter 4. This approach to some extent corresponds to the hypothetico-deductive way of producing scientific knowledge.

The two different kinds of institutional pedagogies were present in different ways in the two exhibitions compared in Chapter 4. In 'Follow the Track' at Experimentarium, discovery pedagogy clearly influenced the final exhibition; in 'The First Dinosaur' at Geocenter Møns Klint there was a more explicit disciplinary anchoring which was directly reflected in the practical science literacy of visitors. Specifically, this disciplinary anchoring was expressed by visitors' understanding of paleontological practice, including their sense-making of the inquiry-based excavation table. Because the excavation game makes use of the *discovery pedagogy* typical of science centers but also features the objects typical of museums, it reflects the complex hybrid status between an object-based museum and an experiment-based science center evident at Geocenter Møns Klint. This unique status of the Excavation Table, representing as well museological as experimental features in addition to a diverse array of both Vision I as Vision II learning outcomes (as presented in fig. 4.10.), prompted me to use this exhibit as a case study. In the following, I use the development of the Excavation Table to investigate how the disciplinary knowledge of paleontology in this case was transposed into a didactical milieu in the form of an exhibit. From this development process, I extract important implications for design to formulate a design model.

## 5.2 Theoretical framework

The excavation table employs principles of scientific inquiry such as problem-solving and learning through participation and experiences (Chikone and Kissel, 2014), described by several authors as a way to enhance the motivation of learners (Artigue and Blomhøj, 2013; Skydsgaard, Andersen and King, 2016). However, in the case of the Excavation Table, the principles of inquiry-based science education were informed by notions from the theory of didactical situations (TDS; Brousseau, 1997/2002; see also Chapter 1 of this text). TDS and inquiry-based science education both hold that the activity of learners should, at times, be similar to the activity of scientists (cf.

Crawford, 2014 and Brousseau, 2002). However, TDS goes a bit further in specifying the conditions of this ‘activity of learners’. In particular, from TDS emerges the *epistemological hypothesis* (Brousseau, 1997/2002) which became pivotal for the design of the exhibit.

The epistemological hypothesis claims that for any existing object of (scientific) knowledge, there is a corresponding *situation*, defined by specific conditions, that can prompt learners to re-create that object of knowledge (Brousseau, 1997/2002; see also Winsløw, 2006). For example, if the goal is for learners to construct chemistry-related knowledge about e.g. Charles’ Law, the original situation that prompted Jacques Charles to formulate Charles’ Law can be used as a model for the design a situation for learners to re-construct Charles’ Law (cf. Achiam, 2013). The translation of the original situation that created an object of knowledge into an educational situation that can cause learners to re-create that knowledge is what is described by *didactic transposition* (Chevallard & Bosch, 2014).

Applied to exhibit design, the epistemological hypothesis suggests that ‘the researcher’s praxeology [can be used] as a template to construct a potential learner’s praxeology that can then be embodied in an exhibit design’ (Achiam, 2013, p. 221). In the specific case of the Excavation Table, the designers thus used the praxeology of the paleontologists who excavated the phytosaurs on the 2016 Greenland Expedition as a template or model for the situation embodied by the interactive, digital game to be encountered by visitors.

In terms of TDS, the excavation game represents a *didactical milieu* (cf. Brousseau, 1997/2002) in which the player can re-create or re-construct content knowledge of the phytosaurs (Vision I) as well as procedural knowledge of how knowledge is created in natural history and paleontology (Vision II). When encountered by visitors, the excavation table can be considered to represent what Brousseau (1997/2002) designates as an *a-didactical* situation in the sense that no teacher is present. However, a narrative voice built into the game instructs the participants in the beginning of the game by explaining the task, keeping track of time during the game, giving notifications when each new fossil is uncovered, and relating the discovered fossils to the possible hypotheses. I would therefore describe the Excavation Table as a *didactical game* with the characteristics of both *didactical* and *a-didactical situations*.

## 5.3 The development of the Excavation Table

As described in Chapter 3, the Excavation Table was designed in the aftermath of a second dinosaur expedition to Greenland in 2016. The exhibit was designed on the basis of the new scientific discoveries made during that expedition as well as the paleontological hypotheses these discoveries gave rise to. The Excavation Table is an interactive, digital game that invites its players to discover fossils in virtual layers of sediment, and to use the fossils and the sequence in which they are discovered to construct hypotheses about the event leading to their formation. Because the Excavation Table is based on the authentic expedition environment, it invites players to experience authentic paleontology on their own bodies in the form of a paleontological excavation setting.

In the development of the table, we (my co-designers and I) used the disciplinary features from the paleontological excavation on Greenland and integrated them into the inquiry-based gaming concept, allowing players to learn – in an epistemological sense - how paleontologists reason in the field, and how this discipline develops and qualifies theories about life in the ancient past. In doing so we allowed the players to be confronted with several of the 'styles of reasoning' described by Kind and Osborne (2017), and especially the 'probabilistic reasoning' (use of likelihood and parsimony) and 'historical-based evolutionary reasoning' (multi-hypothetical methodology) which represents the core-methodology of the paleontological question embodied by the table. The Excavation Table also combines several of the unique disciplinary characteristics of paleontology presented in section 2.2 in Chapter 2. In table 5.1, I outline how, together with the design team, I used the educationally relevant aspects of paleontology (developed in section 2.2.3 of this text) as a guide for the deconstruction and reconstruction of paleontology in the making in the development of the Excavation Table. More specifically, the second column in Table 5.1 could be seen as 'knowledge(-values-practices) to be taught', whereas the third, right-most column could be seen as 'taught knowledge(-values-practices)'.

By using the educationally relevant disciplinary features of paleontology, the excavation table transposes a complex scientific situation into a series of concrete tasks. However, the ontological status of 'science in the making' was also expressed in other aspects of the design process. If we consider the genesis of the Excavation Table further in the light of the didactical transposition, certain features stand out in relation to 'science in the making' (to be continued below table 5.1.).

**Table 5.1.** Application of educationally relevant aspects of paleontology to the exhibit the *Excavation Table.* See section 2.2.3 for further details on the educational relevance of paleontology.

| Kuhn's disciplinary matrix | Educational relevance of paleontology (cf. section 2.2.3) | The Excavation Table |
|---|---|---|
| **Theory and symbolic generalizations** | Engaging learners in the inductive reasoning patterns that mirror those of the paleontologists. | Collecting and using fossil evidence to support one or more competing hypotheses, and grounding the disseminated science in the specific case of the 2016 expedition to Greenland. |
| **Epistemic and ontological beliefs** | Letting learners develop paleontological techniques in an authentic paleontological context | Encouraging coherent thinking by situating the table in the 'expedition room', and by applying meaning to the chronology of the sedimentary [virtual] layers, allowing for realization of 'deep time' and coherence of past and present times, as a part of the reasoning process. |
| **Values** | Presenting the value of explanatory reasoning, | Alternating between multiple hypothesis that co-exist and whom all explain the fossil evidence in [sometimes subtle] different ways (the 'smoking gun' representing the exception that only supports one hypothesis). |
| **Exemplars** | Using fossils with strong visual cues | Finding for instance the articulated fish that indicates the presence of open water, and thereby supports the hypothesis of the phytosaurs dying at the last watering hole. |

First, at the time of the development of the Excavation Table, the scholarly knowledge(-values-practices) in question had not yet been institutionalized, since at the time of the exhibit design, the new knowledge had not yet been published in any scientific papers but came directly from the scientific source (thus creating part of the authenticity). In other words, the transposition of knowledge happened very rapidly, without the usual *transposition delay* caused by e.g. the time it takes the scientific community to construct a stable definition of a conception (Quessada & Clément, 2007; Clément & Castéra, 2013). Indeed, the time that passed from the establishment of the new scientific knowledge (in the analysis of the fossil data immediately following its discovery) until its transposition into taught knowledge (in the form of the interactive game) was defined by the design phase of the table, which began shortly after the return from Greenland.

In terms of presenting science as authentically as possible, I consider this lack of *delay* as favorable, due to the opportunity it provides for engaging non-scientists in a first-hand experience of scientific research. Galloni (2013) discusses a related case, with students following the authentic methods and approaches of anthropology as part of a 'real' anthropological study, and thus enhancing emotions like curiosity, passion, discipline and divergent thinking in the participating students (Galloni, 2013). However, according to Achiam and Johannsen (2015), a short didactic transposition delay can also in some cases be problematic. In the example presented by Achiam and Johannsen (2015), secondary school students collected samples for analysis using laboratory methods that were simultaneously being developed by researchers. The attempt to have students produce data in a real scientific environment using relatively untested laboratory protocols caused educators to worry that the students would not be able to produce (valid) results. This, in turn, caused the educators to intervene activities in the laboratory to a degree where they actually prevented the students from feeling any real engagement with the scientific process (Achiam & Johannsen, 2015).

Considering the learning outcomes from the visitor observations in Chapter 4, however, the diversity of as well Vison I as Vision II (Roberts, 2007) outcomes prompted by the Excavation Table indicate that the simulation of an authentic paleontological situation in combination with the inquiry-based 'science in the making' had the intended effect of stimulating scientific reasoning and engagement. The development of a practical design model described in the following aims to integrate these educational experiences by translating them into practical steps for exhibition designers to follow or consider.

## 5.4 A new design model

In recent decades, a number of models have been developed for the purpose of guiding exhibition design. In the book 'The Educational Role of the Museum' from 1999, Grasso and Morrison describe the stepwise procedure of designing the exhibition 'American Encounters' in the National Museum of American History in Washington, DC. They divide the design process into 12 schematic steps from developing the original ideas to defining the exact objects, textures and logos in the exhibition narrative. In the second step of their scheme, Grasso and Morrison describe the so-called bubble diagram first proposed by McLean in 1993 and elaborated further by Chicone and Kissel (2014) in a chapter of their book 'Dinosaurs and Dioramas – the Creation of Natural History Exhibitions. The bubble diagram consist of 'bubbles of ideas' linked to the general theme or narrative of the exhibition. As such, the bubbles – or sub-themes – can be used to illustrate the general story line, and to connect thoughts and concepts, to create a thematic framework (Chicone and Kissel, 2014). It can additionally, but not necessarily, be inscribed upon a physical map of the exhibition space, allowing this map to 'introduce ideas about desired visitor circulations' (Chicone and Kissel, 2014, p 63). The bubble diagram and schematic presentation of the design process represents a structural tool in the creative and at times chaotic process of transposing a scientific theme into a physical exhibition environment.

Guler (2015) presents an even more structured tool, using a circulation checklist from already existing exhibitions to optimize exhibition design in new exhibitions with special emphasis on visitor circulation patterns (within the fine arts). However, Pekarik (2010), along with his critique of outcomes-based evaluation, suggests a much more qualitative and evolutionary design model beginning with a so-called 'embryonic' exhibition, after which qualitative studies of interacting visitors influence the further development of the 'embryo' into a fully-grown exhibition. In contrast, Achiam (2013) suggests that the didactical concept of *praxeology* be used as part of a content-oriented design model that addresses the link between exhibition features and visitor activities, as well as the transposition of scientific knowledge (in the shape of praxeology) into exhibition content for visitors to experience. Skydsgaard, Andersen and King (2016) discuss the use of certain design principles in exhibition design, and suggest principles that specifically target to influence visitor' motivation and interest and encourage reflection (Vision II outcomes), like *curiosity*, *challenge*, *narrative* and *participation*.

In the present study, the link between the exhibition features and the visitor engagement instead lies in the dissemination of the scientific enterprise (i.e. specific scientific knowledge-values-practices), and in the following, I employ such disciplinary methodology into a concrete design model with the specific emphasis of implementing it into a physical exhibition 'milieu'.

From my findings throughout this dissertation, I recognized three levels of particular importance regarding the successful integration of disciplinary knowledge-values-practices into an exhibition. Those levels roughly followed the levels of co-determination defined by Achiam and Marandino (2014) to fit the museum context, and they consisted of: The decision-making, the design strategy and the implementation into the exhibition 'milieu' (fig. 5.2.)

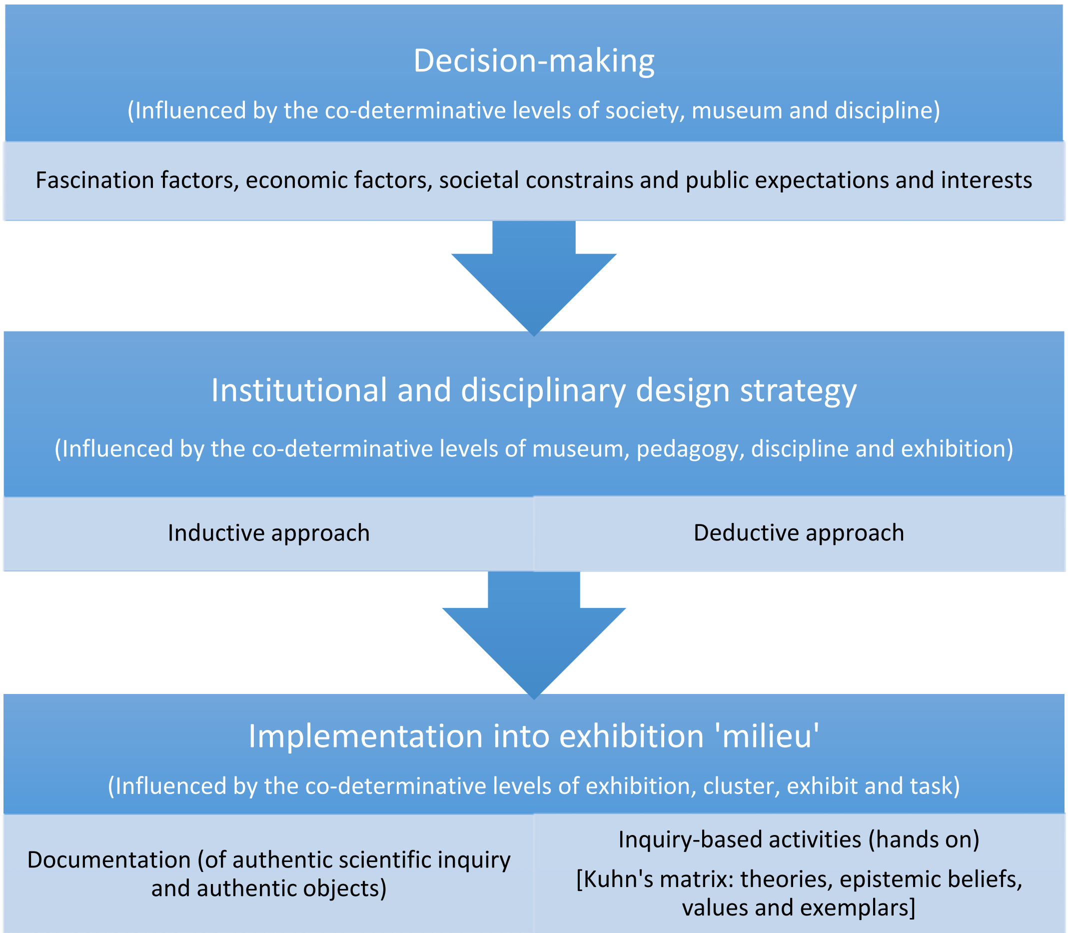


**Fig. 5.2.** A design model for implementing disciplinary knowledge-values-practices into exhibition design with the ontological status of 'science in the making'.

**Decision-making:** The first level of importance is the primary decision regarding *what* to disseminate. The choice of discipline might be given by the nature of the institution (in the case of a geocenter, the disseminated content should be related to geology), but it might also be under the influence of economic factors, societal constraints and public expectations (co-determinative level of **society**, by Achiam and Marandino, 2014), as discussed in chapter 3. In the case of the dinosaur decisions discussed in chapter 2, the reasoning behind the choice of disseminating paleontology, was highly influenced by the *dinosaur effect*, which combined financial needs with disciplinary qualities. In other words, the dinosaur effect can be seen as the utilization of the fascination dinosaurs hold for many visitors to attract paying visitors (financial constraint at the **museum** level) as well as attaining certain educational goals within the **discipline** at stake (see interviews section 2.3.4.). Deciding how to represent the ontological status of the discipline in question, however, could be influenced by either the nature of the chosen discipline or the nature of the desired learning outcomes, bearing in mind that the present findings indicate that 'science in the making' has the potential to affect scientific literacy. As discussed in Chapter 2, paleontological methodology has characteristics that make it especially suited to the dissemination of the scientific process - or 'science in the making', whereas 'ready-made science' - or the display of scientific products - is an ontological status that is more commonly employed as a strategy in traditional museum dissemination (Carnall *et al*, 2013).

**Design strategy:** After deciding on a discipline and the ontological status of its dissemination, the next level of importance is the design strategy to be employed. My empirical findings suggest that in the two instances of exhibition design studied here, the deconstruction of scholarly paleontological knowledge was subject to either an inductive approach based on paleontological objects and content knowledge, typical for museums, or a hypothetico-deductive approach typical of the experimental scientific disciplines and aligned with the specific *discovery pedagogy* typical for science centers. Indeed, the two institutions studied here hints at their institutional design strategy already in the wording of their names: *Experimentarium* is derived from the word experiment, thereby revealing their institutional anchorage in the experimental sciences (not surprising, given their status as a science center). *Geocenter* likewise implies the hybrid status of Geocenter Møns Klint, the prefix 'geo' targeting their inductive anchorage in the discipline of geology, but the word 'center' revealing their original status as a science center (albeit one that exclusively disseminates the geosciences). In fact, the dinosaur exhibition 'The First Dinosaur' was the first exhibition in this institution to incorporate museological elements into the otherwise predominantly hands-on based permanent exhibitions.

**Implementation:** The implementation of the specific features of a discipline into exhibition elements (co-determination levels of exhibition, cluster, exhibit and task; as defined by Achiam and Marandino, 2014), largely follows the preceding choice of design strategy and manifests the disciplinary qualities in different ways according to that strategy. The inductive, museological approach to disseminate 'science in the making' is to disseminate it in much the same manner as the traditional dissemination of 'ready-made science': documenting authentic scientific enterprise in the form of displays for the visitors to observe passively. The displays might consist of authentic objects or presentations of the scientific enterprise as executed by authentic scientific researchers. In the case of 'The First Dinosaur' in Geocenter Møns Klint, a significant part of the exhibition was the consistent documentation of a specific excavation in Greenland throughout the exhibition in the form of pictures, video recordings and displays of authentic objects. The authentic objects were not only in the form of fossils, but also original tools and utensils from the documented expedition, like hammers, transport boxes and polar bear protective devices.

In contrast, the deductive approach in typical science centers with its foundation in *discovery pedagogy* (Oppenheimer, 1968; Quistgaard & Kahr-Højland, 2010; Crain et al. 2013) is more inclined to employ inquiry-based activities like the case of the Excavation Table at Geocenter Møns Klint. Such activities hold the potential to allow visitors to have epistemological experiences with the methodology of the disseminated discipline. The case study described in the present chapter provides an example of how, for educational purposes, such methodology can be deconstructed into the elements of theory, ontological beliefs, values and exemplars (cf. Kuhn, 1962), and how rapid didactical transposition (Quessada and Clément, 2007; Galloni, 2013) can help bridge the gap between non-scientists and the scientific enterprise.

Finally, after implementing the disciplinary features of choice into the exhibition design, the educational outcome of the **final exhibition** still depends, as earlier mentioned and according to the constructivist philosophy, on visitors' prior knowledge, opinions and other predispositions (co-determination level 0; as defined by Achiam and Marandino, 2014). However, the present dissertation provides reasons to believe that even so, the nature of exhibition design has the capacity to influence scientific literacy, and that the application of 'science in the making' has the further potential to evoke certain kinds of scientific enthusiasm amongst visitors, with the potential benefits of enhancing their scientific motivation in the future.

The following and last chapter summarizes findings and conclusions from each of the preceding chapters, as well as outlines the perspectives for future research of the subject, including the potential use of the here developed design model.

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# Chapter 6
# Conclusions and perspectives for further research

In this final chapter, I give an overview of the conclusions of the preceding five chapters and discuss the perspectives they hold for future research. As stated in Chapter 1, the dissertation presented here represents a substantial part of the output of an industrial PhD that investigates the following research questions:

> **Research question 1**: In what way is natural history and the discipline of paleontology different from other branches of science in terms of disciplinary and educational qualities? How are such qualities relevant for exhibition dissemination, and how are they best implemented in the dissemination strategy?
>
> **Research question 2**: Which factors affect the design process of exhibitions, and how can such a design process be optimized so that the integration of a specific disciplinary knowledge and the exhibit elements allow visitor outcomes to correspond to as well the disciplinary potential as the original designer goals? What kind of strategy can be applied to achieve such goals?
>
> **Research question 3**: How does the ontological status of paleontological content matter (science in the making or ready-made science) influence the transposition of scholarly knowledge into content knowledge in an exhibition context, and how can this ontological status influence scientific literacy in visitors?

## 6.1 Summarizing conclusion

The exploration of the first research question in Chapter 2 had both theoretical and empirical aspects. Theoretically, I (along with my co-author) conducted an *a priori* analysis of the discipline of paleontology within the scientific branch of natural history. This analysis investigated and identified the educational significance of the disciplinary qualities that are unique to paleontology, including for instance retrodictive and explanatory reasoning in a multi-hypotheses context.

Furthermore, the qualities of paleontology that are relevant for industrial purposes (i.e. in this case, dissemination in science and geology centers) were further investigated in email interviews with decision-makers from institutions with current dinosaur exhibitions. These decision-makers discussed their decisions to implement dinosaur exhibitions in terms of societal constraints and economic factors, but also discussed rationales related to the discipline such as the value of authenticity and fascination in the dissemination of paleontological content.

The exploration of the second research question in Chapter 3 found conditions and constraints from a wide range of co-determinative levels to influence exhibition design. In particular, and perhaps not surprisingly, conditions originating at the level of discipline were found to be a significant co-determinant in the design of exhibitions aiming to disseminate 'science in the making'. Further, the empirical evidence discussed in Chapter 3 contributed towards the development of a practical design model (in Chapter 5) for future implementation of disciplinary features and 'science in the making' to exhibition design.

The third research question empirically explored the relationship between the ontological status of the exhibited content matter and the visitors' experiences with it in Chapters 3 and 4. The studies reported in these chapters found features such as rapid didactical transposition, the representation of disciplinary knowledge-values-practices 'in the making', and the resulting engagement of visitors with an authentic scientific milieu to positively affect scientific literacy among visitors; this effect included science literacy (Vision I) as well as scientific literacy (Vision II).

## 6.2 Perspectives

In the work presented here, I have sought to develop a coherence between, on one hand, the more theoretical questions of what defines a discipline (paleontology) and what characterizes exhibition design, and on the other, the concrete work of exhibition design practitioners. In this sense, my research is located in the intersection between theoretically driven works of research (relating to, for instance, didactical transposition or the nature of scientific disciplines), and the literature presenting more practical aspects of exhibition design (for instance, in the form of handbooks and manuals). I see two emergent perspectives for science exhibition design research and practice: The dialectics between theory and practice, and attention to the characteristics that define a given discipline to be taught. I shall discuss these perspectives in turn.

First, an important step in developing exhibition design research and practice is to consider the dialectic between more theoretical research and more concrete design practice. This dialectic could, in my opinion, be understood and optimized by including more educational researchers in design teams developing new exhibitions. However, such collaborations are not always unproblematic. Indeed, as part of a recent research-practice project 'PULSE', carried out at the Experimentarium, two PhD students explored such practitioner-researcher collaborations. They report how the lack of a shared rationale between practitioners and researchers constrained the development of PULSE initiatives, creating tension and ambivalence throughout the project (Bønnelycke, Sandholdt, & Jespersen, 2018). The research presented here, more specifically the results reported in Chapter 3, points towards teamwork proceeding un-problematically if individual tasks and goals are well-defined from the onset of the process. This includes ensuring that the competences of each team member supplements those of the others with a minimum of overlap (each corresponding a specific co-determination level), and minimizing the potential conflicts of interest between team members. Clearly, if researcher-practitioner collaborations are to be successful, individual roles and objectives within the collaboration must be defined with respect to competencies reflecting the respective professional backgrounds in either research or in practice.

Another important step in bridging the gap between theory and practice could be a more widespread uptake of design models (such as the one developed here) in at least the planning stages of exhibition design. However, there is risk of devaluing the professional skills of practitioners if they are required to just 'blindly' follow the guidelines laid out by theorists. The design models in question might instead be used as tools to explicitly address the nature and ontological status of science to be disseminated, since recent research has problematized the lack of attention to scientific content in science exhibition design (Achiam & Nielsen, 2016): A lack of attention that may be manifested in terms of a simplistic conception of science (Chicone & Kissel, 2014) or of science as unproblematic, ready-made and taken-for-granted (Quistgaard & Kahr-Højland, 2010; Toon, 2005). The ontological status of content as 'science in the making', meets these critiques by presenting science as an on-going process, un-finished – or even controversial (Latour, 1987; Shapin, 1992; Hine and Medvecky, 2015).

My original objective was to develop a line of argumentation for reintroducing the discipline of paleontology into the current educational system, both its formal and informal aspects. The main part of the dissertation (Chapter 2-4) contributes to this discussion with significant evidence of paleontology and natural history containing educational qualities suited to allow these disciplines to find their place in the educational system once again. It is my hope that they will do so in the near future, and it is my additional experience that an increased focus on the disciplinary subject matter is already being advocated in recent studies and literature. Hopefully, the present work can help this development to continue even further.

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