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ASTROPHYSICS:
DESIGNING FOR INCLUSION

PhD thesis

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ASTROPHYSICS:
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FOR MY MICRO COSMOS

JAKOB, ELLANOR AND ASGER

Abstract

When museums design exhibitions, they create room for experiences that allow the public to engage with knowledge about themselves and the world they live in. However, which publics do they serve? Embedded within the design of exhibitions are values and practices, which may hinder the inclusion of some of the users they are set to serve.

This thesis sets out to understand and address this challenge within a specific frame: planetaria and the topics of astrophysics, space technology and planetary science. Astrophysics is viewed as a gateway to science, due to its ability to create awe. However, in the culture of astrophysics there is a persistent degree of gender imbalance. Thus, this thesis asks if this gender bias becomes unintentionally reproduced in the exhibitions on astrophysics, space technology and planetary science? If so, how can we design exhibitions and present astrophysics in a way that are more inclusive to a greater diversity of users?

The retrospective part of this thesis focuses in on planetaria and planetaria exhibitions. Paper 1, *Planetariums between experience and enlightenment*, finds that Scandinavian planetarium professionals sees enlightenment and experience as being complementary in the planetaria's dome programs. This finding show the potentials planetaria hold to fully embrace the experiential, aesthetic and affective aspects of astrophysics. Paper 2, *The Implied Visitor in a Planetarium Exhibition* focus, on the Planetarium in Copenhagen, DK, and dominant discourse within their exhibition Space Mission. It finds astrophysics presented as technical, fact based, focussed on individual performances, and that the content is organised through game-like and competitive tasks. We argue that this focus and organisation are characteristics associated with masculinity, and therefore prompt a gendered implied visitor. Consequently, the gendered science of astrophysics gave rise to a gendered exhibition.

The objective of prospective part of the thesis is to address this issue. Through my research, I have explored the potentials in operationalising postmodern feminism in exhibition design by linking theory with practice. In collaboration with the Planetarium in Copenhagen, I took an active part in co-creating the exhibition Made in Space. Through the iterative process of a design-based research method, I have collaborated with planetarium professionals, designers and users to experiment with how to design more inclusive experiences. Through this process I formulated design conjectures, or design assumptions, of how to best approach the topic of astrophysics, so that it becomes more inclusive for those who prior to this, have not felt capable of or interested in engaging with the abstract knowledge of astrophysics. These design conjectures are based in theory, qualified and reformulated through users collaboration, and embodied in the final design of the exhibition. The development and implications of the design conjectures and focus on operationalising postmodern feminism are discussed in paper 3, *We are part of the Universe, the Universe is part of us':Transforming the astrophysics in the Planetarium* and paper 4, *Made in Space: Operationalising postmodern feminism in exhibition design.*

In chapter 5, the interactions with and dialogues between the actual users of the new exhibitions were analysed, in order to establish whether the embodied design conjectures lead to the intended meaning-making and outcomes. This final analysis also acts as the backdrop for the final theory development and formulations of design framework. This framework includes the three general design guidelines for designing more inclusive exhibitions. These are:

1. **Linking or connecting the concrete (e.g. the users body) and the abstract (e.g. the universe) enables the users to, and makes them want to, engage with abstract knowledge**

2. **Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making**

3. **Providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways.**

Finally, this thesis presents in paper 6, *Museums Beyond Neutrality* an outlook both for practice and future research, in how museums and out-of-school science institutions can address the challenges facing the museum world and our society at large, by increasing their relevance and inclusiveness to the public.

Abstract in Danish

Når museer udvikler og designer udstillinger, skaber de plads til oplevelser, hvor museets besøgende - brugerne - kan fordybe sig og opnå viden om sig selv og den verden, vi lever i. Men hvilke brugere er det i virkeligheden museer når? Internationale undersøgelser viser at den viden museerne formidler ikke er lige tilgængelig for alle, og der kan være forhold i udstillingsdesignets værdier og praksisser, som kan medvirke til at nogle af de potentielle brugere ikke føler sig inkluderet.

Denne afhandling har til formål at forstå og udfordre denne problemstilling inden for en specifik ramme, nemlig: Planetarier, som formidler emnerne astrofysik, rumteknologi og planetarisk videnskab. Astrofysik er blevet anset som en oplagt vej for brugerne ind i naturvidenskaben på grund af astrofysikkens evne til at skabe fascination. Imidlertid er der i kulturen omkring astrofysikken en vedvarende repræsentation af faget som værende associeret med det maskuline. Det giver en ulighed som i faget som blandt andet ses ved at flere mænd end kvinder er professionelt engageret i faget. Derfor spørger denne afhandling: Bliver den ulighed vi ser i kulturen omkring astrofysik utilsigtet reproduceret i udstillingerne om astrofysik, rumteknologi og planetarisk videnskab? Hvis den gør, hvordan kan så vi designe udstillinger og formidle astrofysik på en måde, der er mere inkluderende for en større mangfoldighed af brugere?

Den retrospektive del af denne afhandling fokuserer på planetarier og deres eksisterende formiling. Den første artikel, *Planetariums between experience and enlightenment* undersøger, hvordan skandinaviske planetariefagfolk ser oplysning og oplevelse i deres planetaries dome-programmer. Analysen viser, at de ser dem som komplementære, og dette taler derfor ind i planetariers potentiale for at udforske of formidle de oplevelsesmæssige, affektive og æstetiske aspekter af astrofysikken. Artikel 2, *The Implied Visitor in a Planetarium Exhibition* fokuserer på udstillingen 'Space Mission' på Planetarium i København, og analyserer de dominerende diskurser i valg af indhold og opsætning. Analysen finder, at astrofysik og rumteknologi bliver præsenteret med et fokus på det tekniske indhold, opstilling af fakta, og som en videnskab båret af individuelle indsatser. Dette indhold er organiseret gennem spillignende og konkurenceskabende opgaver. Vi argumenterer for, at dette focus og organisation af indhold er fundbundet med, hvad der kulturelt set opfattes som maskuline karakteristika, og derfor foreskriver en kulturelt kønnet *impliceret besøgende*. Den retrospektive del af afhandlingen konkluderer derfor, at den kulturelt kønnede astrofysik blev reproduceret i en kulturelt kønnet udstilling, og at dette har indlydelse på hvilke brugere der føler sig in- og ekskluderet.

I den prospektive del af afhandlingen er formålet at adresserer denne problemstilling. Gennem min forskning har jeg undersøgt potentialerne i operationalisering af postmoderne feminisme inden for udstillingsdesign. I samarbejde med Planetarium i København deltog jeg aktivt i at skabe udstillingen 'Made in Space'. Operationalisering er sket gennem designbaseret forskningsmetode, som kobler teori med praksis. Den iterative design proces er sket i et samarbejde med planetariumsfagfolk, designere og brugere

for at eksperimentere med, hvordan man designer mere inkluderende udstillinger. Gennem denne proces har jeg formuleret designformodninger som er baseret i teori og afprøvet i parksis. Formodningerne beskriver, hvordan man bedst kan tilgå emnet astrofysik, så det bliver mere inkluderende for dem, der ikke har følt sig i stand til, eller interesseret i, at engagere sig i den abstrakte viden, som faget indeholder. Designformodningerne er blevet inkorporeret i det endelige design af udstillingen. Artikel 3, *We are part of the Universe, the Universe is part of us':Transforming the astrophysics in the Planetarium* og artikel 4, *Made in Space: Operationalising postmodern feminism in exhibition design* gennemgår og diskuterer udviklingen og implikationerne af design-formodningerne og operationalisering en af postmoderne feminisme i udstillingsdesign.

I kapitel 5 i denne afhandling undrsøges samspillet med, og dialogerne mellem, de faktiske brugere af de nye udstillinger for at fastslå, hvorvidt de inkorporerede designformodninger havde det ønskede resultat. Den endelige analyse fungerer også som baggrund for teoriudviklingen og formuleringen af designrammen.

Designrammen inkluderer tre generelle designretningslinjer til design af mere inkluderende udstillinger:

1. **Forbind det konkrete fx. brugerens krop og det abstrakte fx. Universet. Det gør det muligt for brugerne at engagere sig i abstrakt viden**

2. **Skab fælles oplevelser, der kan fører til debat og diskussion om komplekse emner. Det muliggør fælles meningsdannelse**

3. **Giv plads til åbne spørgsmål i en immersiv oplevelse. Det giver brugerne mulighed for at nærme sig abstrakt viden på fantasifulde og følelsesmæssige måder**

Endelig præsenterer denne afhandling i artikel 6, *Museums Beton Neutrality,* et perspektiv både for praksis og fremtidig forskning i, hvordan museer og videnskabelige formidlingsinstitutioner kan tackle de udfordringer, som museumsverdenen står over for, ved at øge deres relevans for, og inklusion af, befolkningen.

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Thank you

Prologue

This prologue serves as an introduction to the researcher behind the research, both as is custom in critical theoretic writings and to place this PhD project in context that is relevant to its contents. The prologue portrays my personal change from a positivist to a critical theorist, from a closeted feminist to a feminist activist, and from a non-science person to a science graduate.

From unaware positivist to critical theorist

This study lies within the critical theory paradigm, and I now view myself as a critical theorist. As a consequence, I do not see myself as being removed from the research which I take part in, and I will therefore briefly relate my own journey as a researcher. This thesis moves form the interpretivist epistemology in the relativist-contextualise paradigm into critical theory. As a researcher, I have moved, through the course of this PhD, from a classical positivist stance to a critical theorist. The positivistic stance stems from my academic career in the field of geology. I will albeit not make the general claim that all geologist, or the field of geology, share this stance. However, in my own venture into this 'historic science', I would interpret subjective observations believing them to be objective, or at least close to objective. In this field, the empirical arguments rely on your ability to recognise structures and characteristics of a certain 'object' (in my case, microfossils). As my former professor in sedimentology would continually state, 'A good geologist is one who has seen many rocks'. With experience came sight, and with sight came knowledge. Imbedded in this evolution is the understanding that not all geologists would see the same thing. It is therefore hard to argue for objectivity when interpreting traditional geological data. I see that now. So, moving from the field of geology did not only mean moving from Østre Voldgade 10 to Østre Voldgade 3, but also moving from one research paradigm to another.

In my first months (perhaps longer), I struggled with how to make my contribution to the field objective, to remove it from me, as a researcher. I thought that this would move it up into a higher level - a level of, if not absolute, then close to an objective truth. I talked about pre-, post-tests, about studying motion-cams of visitors' movements in exhibitions. I wanted to find methods in which to quantify what the visitors learned using different modes of interaction—to create maps, graphs, and tables, which where to me familiar and intelligible scientific objects. I saw learning and experience as being entities which could be measured, counted, and placed in a taxonomy in order to create a generalisable truth.

Now I understand that even though we might be able to 'measure' experience, to place sensors on the visitors' heads, and generate a graph of when they were scared, happy, sad, or excited, this is not always the most desirable form. I began to understand how qualitative studies can inform us, and how they can provide us with, if not with final answers, then at least new perspectives and understandings, as well as ideas for which questions to ask next. When dealing with a topic as fluid as gender, inclusion, and equity, I understand that my contribution will never be a correct answer, but a step on a continuous road. Indeed,

this is an understanding that has transformed me in these last four years. However, it is not the only thing that has changed me.

From closeted feminist to feminist activist

I use critical and feminist theory to understand and change one atom in the enormous molecule of science education. In the beginning of my study, during my two-minute elevator talk on my project, I would shy away and argue that I used feminist theory, yes, but I was also very adamant that I was not a feminist activist. When describing my study, my project, and my intentions, I felt that I had to tread carefully, and in fact, proclaim that I was not at activist. However, parallel to my own venture into the gender issue in STEM in 2016, the world changed. #MeToo happened; Emma Watson was a feminist; Meryl Streep spoke out and dressed in all black. Does it disqualify my work if I'm a feminist activist? Would it mean that ideas of critical and feminist theory were rendered unworthy? I'm not sure—but there it is. I'm a feminist activist.

As I began to learn more about feminist theory, reading Butler, Harraway, Harding, Beauvoir, Dawson, and Søndergaard, I began to gain new sight. Just as a geologist, through training, learns how to read the structures of the mountains, I now began to read the structures in our society. More specifically, the structures in which we communicate science, learn about science, and do science. How these structures are influenced by, and influences, our society and culture, and at times reproduce inequitable patterns. The unfairness provoked me. Me as a woman, as a scientist, as a mother, as a citizen—as a natural-science-educated white, Nordic woman from a good family background, living in a wealthy, well-structured, and secure society.

So who am I to speak? How can I justify that *I* get to say the truths of others? How can *I* study inclusion, when I have always been included? I believe the first step is to understand my own position of power, as well as recognise the times I haven't been power-full. In this study I talk about gender inequalities in science, more specifically in astronomy and astrophysics. I talk from a position as a science graduate. However, I invite the reader to briefly follow me as I portray a short anecdotal account of my own life as a science student.

From a non-scientific to science graduate

I come from a resourceful family, one where neither my parents or my sister struggled with maths and science. However, I struggled with science throughout my childhood and youth, and never saw myself as a 'science person'. I felt anxiety, had stomach aches, and was practically afraid of math. However, one part of science did not give me those feelings: the historic sciences, astronomy, archaeology, and geology. These three subjects opened science up for me though their imaginative abilities, though the narratives they could let one tell of the world, the places they could transport one to.

Still, as I began high school, I continued to struggle with science, and almost didn't pass the very simple science test for language students the second year. Understandably, my student counsellor advised me against studying geology. However, during my gap year of traveling, where I (as you do) hiked up volcanos, across glaciers, and down into caves, I became increasingly curious about the processes forming these beautiful natural phenomena, and I wanted to learn more.
I therefore decided to try. If I was able to learn math, chemistry, and physics within a year of studying them as supplementary subjects, I would apply for the Geology-Geoscience at Copenhagen University. And I did it. I got a 10 in Math at A-level, 12 in chemistry and 7 in physics. I'm bragging, but this is one of my greatest achievements. Not because of the grades, but of what they show: that I was able to understand science. I'm still not confident in the traditional science fields. If you ask me what a dress costs after a 70% reduction, or to quickly add numbers in my head, I still get a bit anxious. All this is to say that even though I now have a degree in science, I also understand those who think science is scary—literally scary. I was one of them.

This is how I have evolved as a young researcher, and it has inevitably shaped how I have chosen to conduct research, the themes, and the focus. In the following I present my contribution to the field of developing and designing a more inclusive out-of-school science education. This thesis is thus the physical evidence of my journey as a researcher.

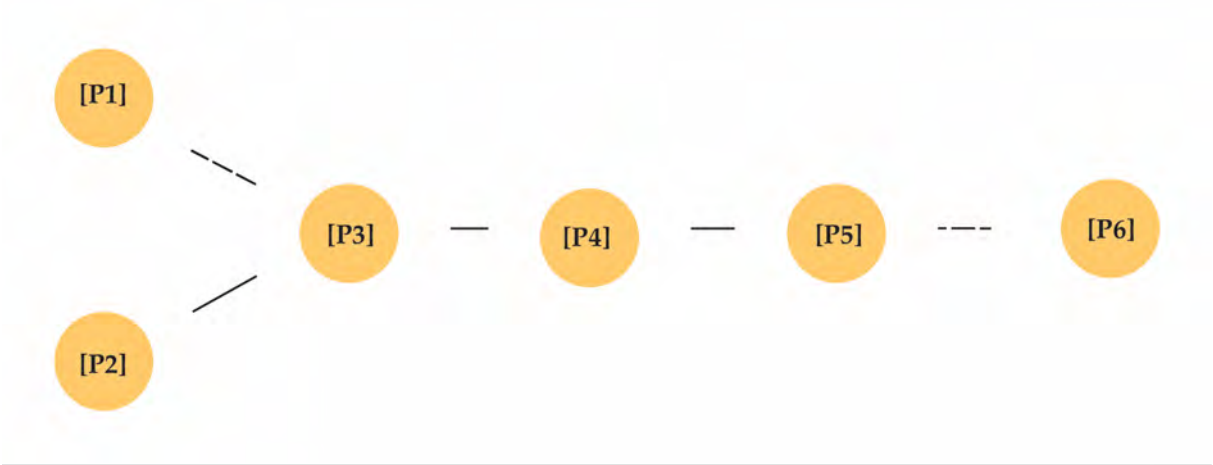


Figure 1: This figure illustrates how the papers of this thesis are related. Paper [P1] and [P2] from the retrospective part of the thesis inform [P3] and [P4], which focuses on the making of *Made in Space*. These are a prerequisite for the analytical chapter [P5]. [P6] are a positioning paper showing reflections upon future museum practice.

Overview

This thesis are the result of a 3-year PhD project. It comprises three papers, one book chapter, one position paper and one analytical chapter (chapter 5 of this thesis). All papers are either published, in press or submitted for publication. Below is an overview of the papers, and how they are placed within the frame of the study (see figure 1).

[P1]	**Paper 1:** Planetariums between experience and enlightenment (Nordisk Museology, published)
[P2]	**Paper 2:** The Implied Visitor in a planetarium exhibition (Museum Management and Curatorship, Published)
[P3]	**Paper 3:** 'We are part of the Universe, the Universe is part of us':Transforming the astrophysics in the Planetarium (in press)
[P4]	**Paper 4:** Made in Space: Operationalising postmodern feminism in exhibition design (submitted)
[P5]	**Chapter 5:** Final analysis of 'Made in Space'
[P6]	**Paper 6:** Museums beyond Neutrality (in review)

This thesis is part of the **Our Museum** research programme, and the research has been carried out in close corporation with the Planetarium, situated in Copenhagen, Denmark. The focus of this thesis is development and design process of their newest exhibition, ***Made in Space***, where I had an active role in co-constructing both the design process and the final design, with key focus on user collaboration. The exhibition opened 1st. of February 2018. This thesis lies within the **critical theory paradigm**. I use **postmodern feminism** to explore issues on (**gender) inequity** within museum representation practice, and I further actively address these issues through co-designing *Made in Space,* by the use of **design-based research (DBR)**. The objective of this thesis is to understand how museums can design more inclusive exhibitions through user collaboration, with the ultimate aim of creating a more democratic access to knowledge and experiences which help form cultural citizenship.


PART 1

1. Introduction

In this chapter, I describe the context this thesis is born out of. I address the more complex and greater issues facing society and give my stance on the role of science, museums, astrophysics and gender in relation to these complexities. I further briefly introduce the research programme, which this thesis is part of. Finally, I introduce the case of the Planetarium and the exhibition Made in Space.

1.1. Motivation

At this point in time, while writing this text, it is hard to overlook one of the main challenges facing the world at large today: the Covid-19 pandemic. This pandemic serves as the most recent example of how misinformation can contaminate the democratic debate, and has only made the inequity in and between societies even more evident, and the need for equal access to knowledge more pressing. The pandemic is but one example, and the pressing issue of access to knowledge is also true for other challenges, such as climate change and gender equity (Sustainable Development Goal 4 and 5, UN, 2015) The pressing issues of inequity is perhaps most evident in the movements, which are at present shaping our society. For example, the #MeToo movement of 2016, which has ignited attention to the issues facing woman in all their diversity, and the Black Lives Matter movement, which has placed the issue of systemic and structural racism at the top of the political debate. These are examples of how 'othering' has created, not only gaps, but also crevasses in our societies. The crises facing our society has made evident the societal structures of inequity between those in power and those without. Structures, which are shaped by race, ethnicity, gender, socio-economic and cultural differences. However, they have also led to action - to change.

Thus, in 2020 we are faced with an increasing need for understanding how we can communicate knowledge that can empower citizens and form the basis for a constructive, democratic debate over the issues facing our societies. The pressing public problems are intertwined with scientific and technical complexity, and the need to bridge gaps that exist between science and public life is more urgent than ever (Kadlec, 2017). In order to bridge this gap, scientists need to take their responsibility of creating connections between science and the public seriously (Kadlec, 2017; Dillon, 2017). Museums and science centres can act as this bridge.

Museums shape us

Out-of-school learning institutions offers people valuable experiences that may affect public scientific literacy, and public debates about science (Falk & Needham, 2011; Lehr et al., 2007). Thereby, they become one of the mayor players in contributing to the informed and engaged citizenship (e.g. Black 2010, 2012; Newman & McLean, 2002). The central issue is that if we want to have engaged citizenship and an informed democracy, these institutions and the knowledge of the diverse disciplines need to be equally

accessible to all. However, museums do not exist in isolation, and the structural inequalities we find in society are therefore also present in museums (e.g. Coffee, 2008; Dawson, 2014a; Feinstein, 2017: Sandell, 2003). Therefore, these spaces can no longer proclaim to be neutral, and are met with increasing demands of accountability, as we discuss in [P6].

This has in the last few decades resulted in an increasing awareness of the role of the museum in society, and the role of the museum in the life of the citizens (e.g. Newman and McLean, 2002). Specific areas of focus have been the de-colonisation of the museum (Knott, 2018; Owen, 2020; Wintle, 2016), the queering of museums (Sullivan & Middleton, 2020), or the attendance to the prevalent White male gaze in exhibitions (Levin, 2010; Robinson, 2017) and how exhibition spaces construct publics through the unintentional use of stereotypical and intelligible ways of preforming gender (Archer et al., 2016a; Dawson et al. 2020).

However, museums can be agents of change (Sandell, 1998), and are indeed morally obliged to be so (Hein, 2011). Museums, in the general terms, are spaces for us to

> … understand or imagine the universe in one or more specific ways. We may come away indifferent or unpersuaded, but we will have been invited to entertain possibilities that, now rendered plausible, could be transformative'
> (Hein, 2011, p. 123).

Hence, museums have the possibility to transform its visitors (Hooper-Greenhill, 2007; Newman, McLean, & Urquhart, 2005; Soren, 2009), and provide new ways for them to understand themselves and their place in the world. Hein (2011) states that 'museum exhibits can affect how people think, what they value and do', and she continues:

> Because it shapes our conception of and accommodation to reality, representation distributes power – and does so unequally. Because representation both limits and enables action, it is political. It defines possibility, opens and closes options. (Hein, 2011, p. 118)

Additionally, as McLean (1999) formulates so adequately, embedded in representation is the material evidence of the presenters' intentions and values. The problem is that these intentions and values may deflect groups of users and ultimately reproduce the inequities percolating society (Dawson, 2014a, 2014b; Feinstein, 2017).

We shape the museums

Although these institutions face different challenges, they share the difficult task of reaching those audiences that are presently (albeit unintentionally) excluded. The first step of addressing the issues has already been taken, namely the awareness of there being a problem in how museums communicate knowledge (Dawson, 2014a; Feinstein, 2017; Hein, 2011; Levin, 2010). The second step is to actively discus how we can address the issues, and to take action.

One way of taking action is to give a voice to those, who traditionally have been excluded. Over recent decades, user participation has been on the rise, and variations and different scales of the same concept coexist (Simon, 2010). When successful, these initiatives are not just islands of experience, which crumbles and are forgotten as soon as the project and its participants move on. They are part of a continuous change and betterment of both the institution and the participants. A change, where both the product and the process of user involvement increase inclusion and awareness.

So, do I expect this thesis to change all issues exemplified above? No. But I hope the reader will follow me once more, as we take a stray path: Before my life as a PhD student in museum research, I used to study and work as a paleo-climatologist. I studied microfossils in marine sediment cores. Each marine core, and the layers of sediment deposited there over thousands of years, tells its own paleoclimatic story. A story of biological-, sedimentary-, oceanographic- , and chemical processes as response to climatic conditions. These processes all contribute to the final layers of the sediment, and by tracing back through the processes, I can read the story of the core. This small core, with a diameter of 15 cm, seems small and can be an easily disregarded dot in the arguably big ocean floor. However, this little dot has it story in its own right. And by combining it with the thousands of cores from around the world, we can begin to map out the general story and understand the development of the climate in the past. Now, however, my focus has changed. I have looked up from my microscope, only to begin studying another seemingly small dot - one single exhibition. One development process, one exhibition, one case. It seems easy to disregard my work. But it is one small dot in the ocean of museum research, and it will help us understand the conditions, processes and future climate in the museum world.

1.2. Our Museum

This PhD project is part of the national research programme, Our Museum, and is one of 13 research projects. The *Our Museum* research community comprises PhD-students and senior researchers from five Danish universities and museum practitioners from eight museum partners. Hence, the Our museum community represent a diverse selection of the museum community in Denmark, including art museums, cultural heritage museums, and science museums including the Planetarium.

As such, this project is shaped by the common aim of the programme, which is to understand how museums has acted - and can act- as a societal agent promoting engaged cultural citizenship. This aim takes a point of departure in two questions: What are the dilemmas regarding the balance between enlightenment and experience that characterise Danish museums' dissemination, both historically and at present; and How can contemporary museum communication be developed, through design and evaluation, to optimise the museum's ability to permanently strengthen the quality of life and citizenship among the population?

In this project the theme of cultural engagement act as a backdrop, in that I have worked understanding *how* we can communicate abstract and complex knowledge in ways so that it breaks the barriers of what I consider stereotypical representation of science as a masculine venture. I do so by involving what I call the *non-users,* meaning those who does not see themselves at being a scientific person, or having a strong link to science, in particular astronomy and astrophysics.

1.2.1. Experience / enlightenment

One of incentive for the Our Museum programme were to further understand how the relationship between experience and enlightenment, as a reaction to the discourse of the museum institutions becoming 'themeparks' through the use of new technical and digital media. This research has been carried out with a retrospective view on the development of the concepts experience/enlightenment though Danish museological history, to further understand the presents perceptions of the two in museum communication. In this thesis, paper 1 [P1] addressees the concepts of enlightenments and experience within a planetarium context, however, a further debate on the concepts are beyond the reach of this thesis.

1.3. The Planetarium

In the Our Museum programme each prospective project is born out of a collaboration between a museum partner and an university partner, linking research with practice. In this project the collaboration partner, and therefore the case for this thesis, is the Planetarium (former Tycho Brahe Planetarium). The Planetarium opened in 1989 in central Copenhagen, and is the largest planetarium in Denmark and among the largest in Scandinavia. In 2016 the Planetarium was in a redefinition process. Like museums they disseminate scientific subject matter to the general public (Ministry of Education, 2000), and like some science centres and museums, the Planetarium has been challenged by falling visitor numbers in recent years. Among its efforts to attract new audiences, the Planetarium had taken a commercial perspective and, as a result, gradually become a 'glorified cinema' (T. Ibsen, pers. comm., 06/08/16). Even so, visitor numbers continued to decrease. In response, the Planetarium launched a new strategy in 2016.

This strategy placed astrophysics, space technology and planetary science at the core of all the Planetarium's activities in order to re-establish its relevance as an out-of-school science education provider in Denmark, and thereby attract more visitors.

As I began the PhD-project, the Head of Science Communication, astrophysicist Tina Ibsen, had just received funding for developing a new exhibition in the largest exhibition area in the Planetarium, named the Tycho Brahe Hall, which were to become the new flagship initiative. The objective of this new exhibition was to present recent Danish research in the field of astrophysics and astronomy. I was therefore invited to be part of the development of this new exhibition, not only studying the process, but also actively influencing and co-designing it. I therefore became an active and involved actor in the development of the new exhibitions, which came to be called *Made in Space*. This leads me to the objective of this thesis.

1.4. Objective

This project sets out to examine astrophysics from a science education perspective. Through a collaboration with the Planetarium in Copenhagen, the project addresses questions related to how to make the complicated and abstract knowledge of astrophysics obtainable, attractive and engaging. The core of this project is the development a new exhibition at the Planetarium, and how, though the development process, the Planetarium can face the challenges of designing spaces that are inclusive to a diversity of publics. It explores how to communicate scientific knowledge in a way that does not only speak to the 'usual suspects', but also provides a possible gateway into science for those who do not readily relate to science in general, or to astronomy and astrophysics, specifically. The ultimate aim is thereby to help provide (positive) experiences that allow the users to see themselves and the world in new perspectives. To this end, the science of astronomy and astrophysics provides prospects, possibilities and problems.


PART 2

2. State of the art

In this chapter I present the three essential fields of research, which this thesis builds on. I do so by describing how they intersect, by first describing astrophysics and gender equity from a historic perspective, how this influence both in and out-of-school learning environments, and finally I briefly present the role of the planetariums in this context.

The research which forms the point of departure of this thesis originates from three (or more) different fields of study; gender studies, astrophysics research, and research in science education in out-of-school institutions (see figure 2). Hence, I do not attempt to provide an exhaustive description of these three well-established research areas; however, in the following I provide an overview of the relevant framings and research efforts that I build my argumentation on.

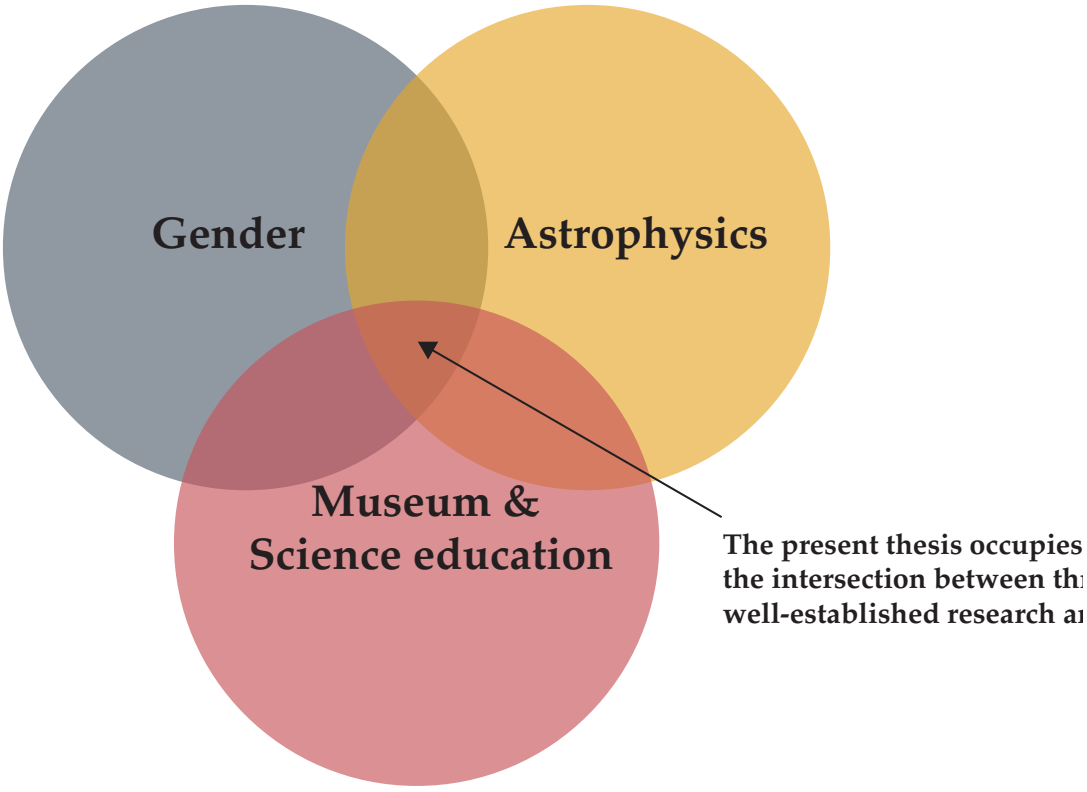


Figure 2: Illustration of the three research areas in which this thesis move, and the intersection which the research presented in this thesis occupy.

2.1. The universe, power, inequality and change

Space has a unifying and universal capability to inspire awe, and has captured and mesmerised humans always. Its unfathomable vastness, and the captivating beauty of the sublime cosmos have been transmitted through poetry, art, philosophy and science alike. Thus exists a diverse array of approaches to how we can view and understand the night sky. It is something that we can, if not fathom, at least not ignore as both a practical and imaginative part of our lives and origin. Due to its apparent ability to inspire curiosity across gender, culture or general inclination toward science (Salimpour et al. 2020), astronomy has often often been designated as a gateway to science (Gonsalves, 2018).

However, the numbers do not support this designation. In the International Astronomical Union (2020), 19% of the membership is female (out of 14.039 members in total). The Danish membership includes 99 members of which 16 are female (16%). At the Niels Bohr Institute (the Physics Department) of the University of Copenhagen, 39 out of 134 accepted new students in 2020 were women (while at the Faculty of Science, 1071 out of 2285 accepted students were women)(University of Copenhagen, 2020). This pattern is also reflected in the (albeit dated) numbers from Denmark on academic employment in astronomy, which show that in 2005, out of 41 research staff, 4 were female. It seems that physics, and astronomy and astrophysics in particular, lag behind other scientific fields in regard to gender balance.

Awareness of this issue is on the rise within the astronomy and astrophysics community, and has resulted in an increase in research that studies these gender discrepancies. The focus of a large part of these studies has been on how gender influences the careers of astronomers and astrophysicists, and there is therefore now substantial evidence on how women (and other gender identities) are marginalised within the field. These studies have looked at underrepresentation of women in astronomy research practices such as time allocation at major observatories (Lonsdale, Schwab & Hunt, 2016; Patat, 2016; Reid, 2014), citations in major astronomy journals (Caplar, Tacchella and Birrer, 2017), the likelihood of asking questions in conference sessions (Davenport et al., 2014; Pritchard et al., 2014; Schmidt et al., 2016; Schmidt and Davenport, 2017), as well as the length of time from completing a PhD to acquiring a long-term position in an astronomy related field (Flaherty, 2018; Perley, 2019).

How can this be? Why are Woman so marginalised and underrepresented within this field? To answer this question, I take a brief detour into the field of history and philosophy of science. Because if we are to change gender inequities we have to begin by understanding where these stems from.

In the following section, I make this argumentation in three steps: The first argument is that knowledge of the skies has always held power. The second argument is that in modern western society, these aspects of power remain and the conscious and consistent exclusion of women from the early professionalisation of science has carved structures in the science research community that we have yet to fully undo. The third

argument is that these structures have affected, and still affect science education, both in and out-of-school.

2.1.1. The power of the sky

Both historically and at present, knowledge of the skies has held aspects of power. From knowing when to plant crops and hunt game, how to navigate across water and land, and when to perform religious rituals and ceremonies (Penprase, 2011; Selin, 2000). These important aspects of human innovation and religious practice has always held connection to power and the powerful (Penprase, 2011), and have consequently contributed to inequality and inequity across societies and time. In fact, Shapin (1990) discusses how historically, astronomy was one of the first scientific areas which developed a gap of comprehension between acknowledged practitioners and the public, creating a divide between of those 'in the know' and those on the outside. In other words, since ancient times, synergies between power and information have created structures of inequity.

2.1.2. Modern western science and the male gaze

The structures of inequity intertwined with the origins of western modern science are still present in the scientific community of today. Schiebinger (1987) describes how during the professionalisation of western science in Europe, as universities and academic societies were formed, the position of women in society became reflected in the scientific community: As women at the time were treated as inferior to men (Saini, 2017), women in science were also suppressed and marginalised. Women were simply not allowed entry to the growing and evolving scientific intuitions, where scientific reasoning and knowledge evolved. This fact created very real structural obstacles for women in science (Schiebinger, 1987, 2010).

Because white, European men essentially shaped early modern science, it is not surprising that the general field of western science is traditionally viewed as a masculine endeavour, both in and outside of academia (Harding, 1991). Sandra Harding describes how 'products of thoughts bear the mark of their collective and individual creators, and the creators in turn have been distinctively marked as to gender, class, race, and culture' (Harding, 1986, p.15). Thus, it is becoming less and less controversial to state that science is not neutral and is a product of culture (Harding, 1998; Keller, 1982). The cultural and social structures of western society are carved into the field of science, and the inequities existing in society are therefore mirrored in science. These same structural inequities also linger in the fields of astronomy and astrophysics. Indeed, based on the demographics presented in the preceding, it seems that these two domains struggle to an even greater extent to step out of the inequitable shadow of traditional western science.

Physics is considered a 'hard' science, with connections to 'male' and 'elite' and as such it is produced as both difficult and masculine (Due, 2014; Harding, 1991; Hasse, 2009; Walkerdine, 1989). This discourse within our culture inadvertently shapes what is considered intelligible ways of 'doing' physic (Archer,

2016a; Danielsson, 2009; Francis et al., 2017), leading to these being associated with traits that are culturally and symbolically associated with masculinity (Faulkner, 2000; Francis, 2000; Hasse, 2009). Within astrophysics, Gonsalves (2018) practitioners engage in an ongoing negotiation of how to appropriately perform and be recognised as an 'astrophysicist', or simply a person who is interested and accomplished in the field (Gonsalves, 2018).

However, these scattered pieces do not stand unnoticed or unrecognised, the community is at large now actively facing these issues. Nature astronomy had in 2014, and again in 2019 a focus issue on inequity and inequity within the astronomy community. Here, the focus is on gender equality (Kewley, 2019), unmuting the indigenous voices (Venkatesan, 2019), scrutinising and critiquing elusive cultures in academia (Johnston, 2019) - how this s now beginning to change (Primas, 2019; Usuda-Sato, Mineshige, & Canas, 2019). This thesis is part of this movement, as it takes the initials steps into how out-of-school science education institutions can create a more inclusive presentation of astronomy and astrophysics

2.1.3. Formal science education

The gendered structures found in science research stereotypical representations are reproduced (and perhaps amplified) within formal science education. When any body of scientific knowledge moves from the academic sphere and into the diverse sphere of education, communication and dissemination, it undergoes change. However, this process of translocation and transformation ('didactical transposition') does not take place in a closed system. Embedded in this reconstruction are this are values, practices, and dominant discourses which influence how the knowledge is restructured (Bosch & Gascón, 2014; Chevallard, 2007). Formal education cannot be understood as an isolated activity, but needs to be understood in a broader personal and societal context (e.g. Danielsson, 2009; Brickhouse, 2001), where the students' identities are negotiated and re-negotiated as a response to social and cultural context they find themselves in.

This means that being a physics student is constructed and reconstructed by the prevailing storylines and images of how to appropriately perform and thus be recognised as an acceptable or "good" (astro)physicist (Gonsalves, 2014, 2018). Therefore, the science identities that are promoted in formal educational settings may not be socially available, possible, or desirable to all students (Carlone, 2004; Godec, 2017). As such, it has been difficult for girls (and other minorities not aligning with white, male, middle-class mold) to be recognised as 'good' physics or science students by teachers and peers (Brickhouse, 2001; Carlone, 2004; Osborne et al., 2003). This may lead students to negotiate narrow gendered identities to become socially and academically accepted (Madsen, Holmegaard & Ulriksen, 2015). Thus, formal education shapes how the students see themselves, and are thus a key factor in shaping young people's science identities (eg. Carlone, 2004). It is with these understandings of selves that users enter out-of-school science education environments, such as science museums.

2.1.4. Science and gender in out-of-school science learning environments

Just as in formal education settings, scholarly knowledge produced in the academic realm is deconstructed and reconstructed before it is communicated to the users of the museum (Achiam & Marandino, 2014). However, in the reconstruction lies a choice of what to present and how. This choice is not neutral, and not without implicit values and perspectives of the presenter(s) (e.g. Maclean, 1999). As thus, museums are in risk of excluding those does not comply with these notions and values (e.g. Dawson, 2014a; Feinstein; 2017; Kinsley, 2016).

Feminist critique of museums and science centres have revealed the how the discourses of modern western science are embedded within museum practice. This research has focused on the museums as institutions (Hein, 2010, 2011), on how they represent science and gender in their exhibitions (Levin, 2010; Machin, 2008), and how this affects the way users act within these spaces (Archer, 2016a; Dawson, 2014a). For instance, Amy Levin (2010) analysed how the Natural History Museum in London represents gender in their dissemination of evolution. She identified gendered, even phallic, symbols across the museum exhibits. Thus, Levin argues, museums enforce social norms that reproduce the idea of the western pursuit of science as being the right one, formed by western high society men. Similarly, Machin (2008) studied how gendered stories were told through the exhibition of animals, with a particular focus on how female animals are presented. She found that the exhibitions presented 'androcentric biases through their patriarchal stories masquerading as biological truths' (p. 64). These are but two examples on how museums, which are 'trusted, nonpartisan intermediary organisations' (Kadlec, 2017, p. 40) present both past and present cultural stereotypical representations of gender.

How the museums present their knowledge is relevant, as the representations in exhibitions create a specific script for users to follow (cf. Marandino, 2016; Oudshoorn, Saetnan, & Lie, 2002). Dawson (2014) has found these scripts to be 'structured in ways that 'othered' those who were not 'ideal' visitors. This prevented 'othered' visitors from accessing the science learning and engagement opportunities designed by the institution' (p.1103). Further, Archer et al. (2016a) and Dawson et al. (2020) studied the intelligible identity performances in science museum settings for girls and boys, respectively. Archer et al. (2016a) studied the gendered performances of urban boys during a school visit to a science museum. Collectively, their findings suggest that masculinity was privileged and normalised within the museum environment, prompting some of the boys to engage with science through performances of hegemonic masculinity. They further found that these performances were expressed through what they call 'laddishness' and 'muscular intellect', which further excluded and marginalised girls and non-dominant boys (Archer et al., 2016a). Dawson et al. (2020) found that the museum space configured intelligible ways of 'doing science' and 'doing girl', but that these two kinds of performances were difficult to combine and at times even mutually exclusive.

In a way, these results are not surprising. It is well established within museum research that the physical, social and cultural contexts influence museum visitors (Falk and Dierking, 2000). As these contexts shape the museum visits, embedded in the contexts are a stereotypical gendering in how museums present science. These contexts therefore shape which are considered intelligible ways of acting within a museum context, and what are considered and recognised as the 'ideal' visitor profile (Dawson, 2014a).

Hilde Hein has advocated for the implementation of feminist theory into museums' practice (Hein, 2010, 2011). In the context of the museum, she does not see feminist theory as solely representing gender. Rather, she sees it as a vessel to address the challenges of 'othering' that underpins museum policy and practice. Thus, Hein's feminist theory for museums converges with queer theory and post-colonial theory in its focus of transforming museum practice to disrupt the reproduction of 'othering' in museum practice (Hein, 2011).

Feinstein (2017) states that 'the bitter reality is that science museums almost certainly make inequities worse'(p. 533), and he argues for a substantial transformation of the museum world as to not allow the injuries and inequality of the past to continue to provide a rift between those with and without access to knowledge and power. He further argues that the museum community should address this 'crisis' (p. 553), by first unveiling and acknowledging the inequities in museum practice, by prompting researchers to collaborate with museums to address the issues through research and design, and finally by requiring researchers to advocate for systemic change in funding and policy which can help museum take steps needed for the transformation (Feinstein, 2017).
This thesis addresses the two first recommendations with respect to the Planetarium and its exhibition space. I will therefore briefly introduce broad strokes of planetarium-based education research.

2.2. Placing planetaria

Planetaria are often defined by their most dominant feature, the dome-shaped projections screens on which stars, planets and other celestial objects and phenomena can be projected. For this reason, education research in planetaria has often focused on the dome (e.g. Bigg, 2017; Plummer et al., 2015; Plummer, 2009; Slater and Tagte, 2017). Such research has studied the conceptual and cognitive gains made possible by the visualisation opportunities provided by the dome exhibition (Plummer et al., 2015). It has led to, for instance, knowledge about how immersive visualisations within the dome helps undergraduates understand complex phenomena (Yu et al., 2015), and to discussions of how immersive visualisations can help create a spatial perspective that would otherwise have been a heavy cognitive load for the learners, e.g. by keeping track of celestial bodies on a 2D plane (Plummer et al., 2015; Yu et al., 2015).

However, another aspect of the in-dome education research has since the 1950's also had a continuous focus on the affective. In their book on astronomy education research in the planetarium, Slater and Tatge

(2017) argue that 'considering the affective domain is perhaps just as important to planetarium education researchers, if not more important, than addressing the cognitive domain of memory and conceptual understanding' (p. 103).

Another line of research has been within formal astronomy education (e.g. Eriksson et al., 2014; Plummer et al., 2013). This research has focused on the how the use of planetaria in classroom settings can aid understanding of complex phenomena, e.g. the changing seasons (Yu et al., 2015). The formal lessons take place both within the planetarium itself and through the portable planetariums that are introduced into the classrooms in schools (Eriksson et al., 2014; Plummer et al., 2013). The strong focus on the educational role of the planetarium dome is perhaps the reason for the seeming lack of attention to the dissemination of astrophysics in exhibition settings. The present study wishes to address this gap in the literature.

2.2.1. Representing Astrophysics and Astronomy: View from nowhere

Objects or artefacts in a traditional museum sense are scarce in the planetaria. They are often either man-made, e.g. technical objects from a space craft, or moon rocks or meteorites. If we do not include space technologies, the objects becomes even scarcer, as the fields of astronomy and astrophysics deals with phenomena and objects in space, which are often both out of sight and out of reach for us humans. Thus, much of what we see in space is through man-made technologies, enhanced and rendered pictures and simulations (Eriksson, 2014, p. 93). Though it may appear to present to us the unchanged natural gaze into space, everything that is presented has in one way or another been transmitted through a human made device, and as such, it can never be free of the presenter. In astronomy and astrophysics, the observer and the observed is therefore at most times inseparable (Penprase, 2011).

Griffin (2014) argues that the inaccessibility of the large scale structures therefore only can be 'accessed through the imaginaries ' (p.1). This inaccessibility to human scale structures links to my past in geology, where we cannot see the processes we describe due to both spatial and temporal scales and the inaccessibility of the places they occur. As Frodeman (2003) puts it, the geologic seeing therefore depends upon imaginative capacity (P. 115). Therefore, resting on the imaginative capabilities are quintessential when understanding disciplines which transcends space and time. This is as true in the scientific and academic sphere as in the dissemination and communication of these fields.

The lack of tangible human scale objects in astrophysics is both a challenge and opportunity for its dissemination. Exhibition designers (and artists) in many instances need to create objects, be it a model of the moon (Figure 3) or visualisation of a supernova explosion. Therefore, the line between artist and scientist blurs in some instances. Many of the visualisations in exhibitions on space in planetaria, science centres and science museums are therefore an artistic representation of scientific knowledge. As astronomy and astrophysics exhibitions are not limited by objects, exhibition designers can freely re-imagine how to present the scientific content to make it welcoming and inspirational to those who do not readily engage

with 'hard' and 'abstract' science. Thus, I argue that exhibitions on astronomy and astrophysics have a remarkable opportunity to transform how users sees and understands themselves and the world.

Figure 3: Scientific Moon model prepared by Johann Friedrich Julius Schmidt and Thomas Dickert, Germany, 1898. Photo: Field Museum Library / Getty Images

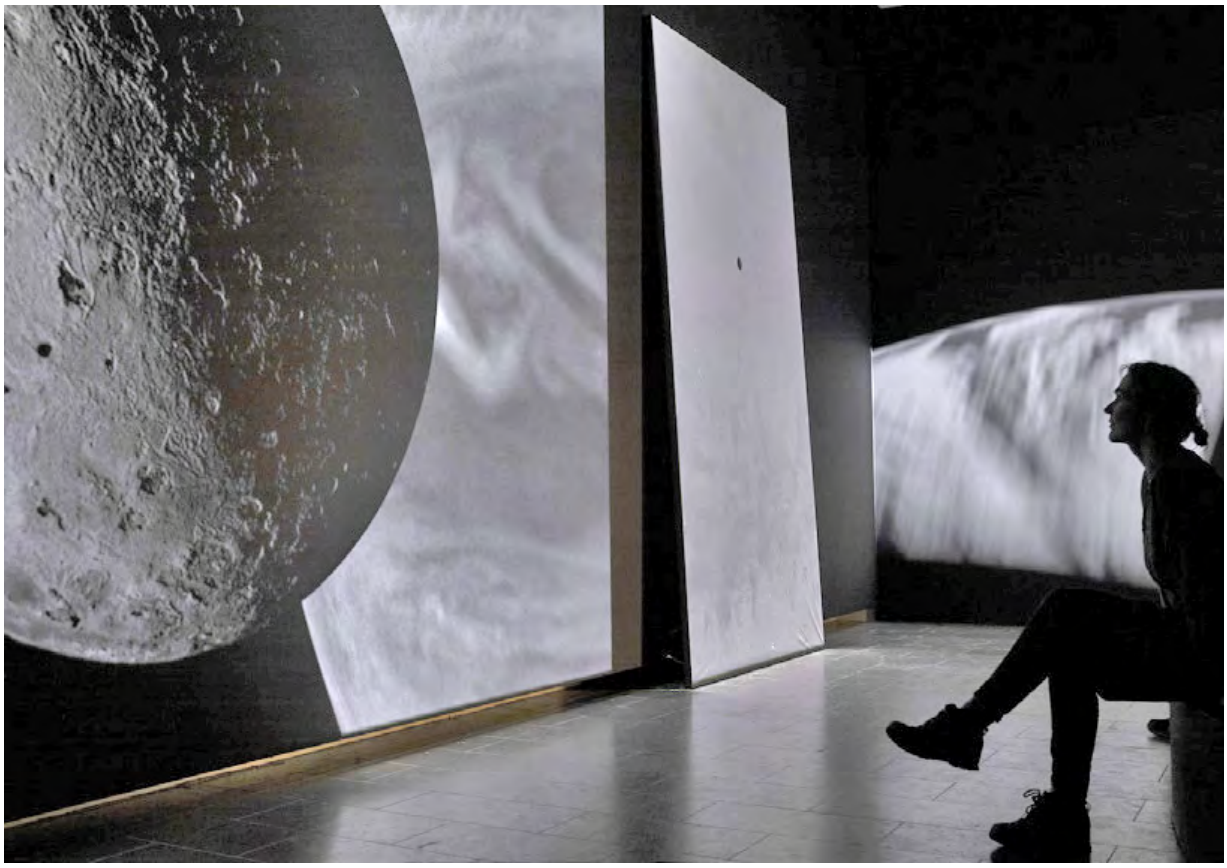


Figure 4: Photo of Marie Kølbæk Iversen art installation, *Io/I* in "The Moon" Louisiana Museum of Modern Art, Humlebæk, DK, 2018 Photo © Frida Gregersen

Another View

Marie Kølbæk Iversen is a Danish artist and her work exemplifies another take and another view on astronomy and astrophysics. Her art works with the connect/disconnect between us and space. She works with natural phenomena, and has an interesting perspective on the connection between arts, science and humanity. In her project Io/I (Io meaning I in in Italian, the language of Galileo Galilei, who discovered Io) she has used NASA's pictures of Jupiter's moon Io (see figure 4). Calling Io by feminine pronouns, she argues that even though Io does not have a physical and tangible presence here on Earth that does not mean that she is not part of the human experience. She sees satellites as an extension of humanity, and therefore an extension of herself. She is not interested in the science of it, but of the narratives the satellites open up for - the extension into the world that we normally are not able to reach (Iversen, 2019). She thus has a very different agenda when she explores the satellite photos produced and made available by NASA, and uses these technical and scientific photos to tell a story of humankind. She very directly forms the link between herself of Io, between her and outer space, using scientifically and technically produced images. She therefore uses 'spacefare for humankind' explicitly in her work. Her use of space-technologies represents an 'other' view on, and value of, space and the universe.

2.3. Research questions

The research presented here is located in a growing number of studies that challenge the norms and tacit assumptions in museum and science communication practice. These norms and assumptions often originate in the scientific disciplines and scientific culture, and are echoed in museum practice. However, my objective is not only to understand, but also to contribute to changing and influencing these norms. I approach this objective by exploring the design of a process and a product that makes the abstract, incomprehensible universe accessible to a more diverse users-group. The overarching research question that guides my research is:

> **[RQ] How is the science of astrophysicists transformed to become the science of visitors in a planetarium setting, and what are the implications of this transformation for the inclusivity of planetarium visitors?**

This question has both retrospective analysis-aspects and prospective design-aspects (see figure 5). I thus break it down into components, where [RQ1] is designed to inform and qualify [RQ2] and [RQ3].

> **[RQ1]** How do present-day planetaria, science centres and museums present astronomy and astrophysics in exhibitions, and what are the implications of these exhibition designs for the gender inclusion of the visitors?

> **[RQ2]** What are the design conjectures of astrophysicists, staff members and design experts working towards the design of an exhibition (especially: what is the gender of the implied visitor in these conjectures), and how can these conjectures be synthesised with insights from gender research to create exhibit design prototypes?

> **[RQ3]** How are the conjectures of the various exhibition developers, regarding astrophysics, astronomy, and the visitor experience, embodied in the exhibition and enacted by visitors to the exhibition? Specifically: how are the gender inclusion aspects of the exhibition realised in the visitor experience, and what are the implications of this realisation for the design of inclusive exhibitions?

In the following chapter I outline the theoretical framing, epistemological reasoning and the general methods I use to answer the above stated research questions.

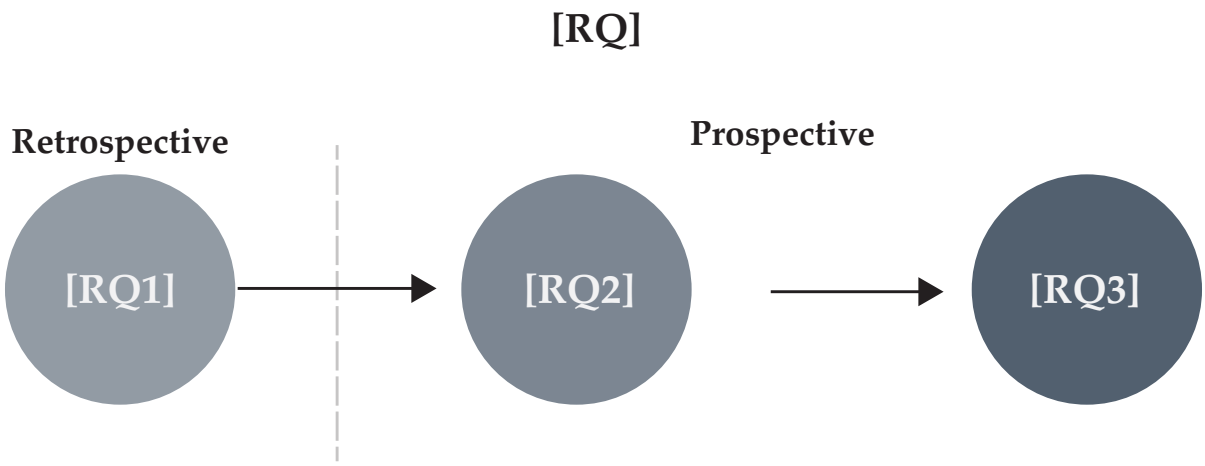


Figure 5: Schematic representation of the research questions and their arrangement. The overall research question [RQ] is answered through the retrospective sub-research question [RQ1], which informs [RQ2] and [RQ3] in the prospective part of the project.


PART 3

3. Methodology

This chapter explains the general framing of this study. The first section describes the research paradigm(s) in which this study is placed; specifically its gradual and purposeful transition from from the relativist-contextualist paradigm to critical theory, incorporating the branch of the feminist theory. I further discuss my standpoint on post-modern feminism and view on gender. The third section explains the tools I use to operationalise post-modern feminism; it therefore briefly introduces design-based research and how I use it in this thesis.

3.1. Epistemological perspective

In the retrospective part of this, the first paper [P1] is situated within what Anderson and Ellenbogen (2012) designates as the interpretivist epistemology in the relativist-contextualist research paradigm. The second paper [P2] and chapter 5 [P5] lies in the intersection between the relativist-contextualist and critical theorist perspective in the critical theory paradigm (Anderson and Ellenbogen, 2012; Treagust, Won, & Duit, 2014). The three papers [P3], [P4] and [P6] from the prospective part of the thesis all represent the critical theorist perspective.

3.1.1. The interpretivist perspective

The interpretivist perspective exists in the relativist-contextualist paradigm in educational research (Anderson and Ellenbogen, 2012). The focus of the interpretivist perspective is that people construct their meanings and understandings based on the context in which it occurs, and is influenced by a multitude of complex variables, such as our cultural, socioeconomic and ethnic background, and our prior experience and interests (Anderson and Ellenbogen, 2012; Treagust, Won, & Duit, 2014). As an interpretivist researcher I sought to discover and understand individuals' situated experiences, understanding that learning situations happen within these complex ecologies. Learning situations can therefore not be reduced to controlled laboratory conditions; nor can meaningful insights be made based solely on positivist pre/post or control/intervention tests using quantitative methods alone (Anderson & Ellenbogen, 2012; Treagust, Won, & Duit, 2014).

The first part of this work, papers [P1] and [P2], represents the retrospective part of my work. It focuses on understanding existing structures within planetariums, through planetarium professionals' views on experience and enlightenment [P1] and how existing exhibitions imply certain visitors [P2]. These studies are set, entirely or partly, in the interpretivist epistemology, as they focus on 'localised understandings of human experience' (Treagust, Won, & Duit, 2014, p. 7), in opposition to the positivist search for an objective and generalisable 'truth'

In papers [P1] and [P2] we understand human experience, that of both planetarium professionals and visitors to museums, as being contextual, temporal, and particular: Contextual, as an individual's experience cannot be removed from the situated context in which it exists; temporal, because an individual's identity is not static, but responsive; particular, as it acknowledges that an individual's ideas, values, and knowledge are shaped by social, political, cultural, economic, gender and ethnic experiences (Anderson and Ellenbogen, 2012; Treagust, Won, & Duit, 2014).

In paper [P2], my co-author and I studied the 'implied visitor'- the human experience that we could deduce through the organisation of an exhibition. As such, we isolated the physical representation, though it had long been well established in museum research that the physical as well as the sociocultural and personal context are all important parts of the museums experience (Falk and Dierking, 2000). One might therefore argue that the 'human', the individual experience described was missing in this case, and we realise that this is an issue. However, in [P2] we argue that the museum experience is shaped by visitors' predispositions as well as their interactions with the exhibition. In other words, the exhibition creates, or dictates, intelligible ways of interacting based on the organisation and presentation of content. The organisation of content, in turn, originates from the institution of the Planetarium, set within the larger culture of astronomy and astrophysics. However, this study does more than just describe the structures implicitly shaping the institutions, its exhibitions and the visitor experience - it focused on how this organisation can act to empower or disempower its visitors. It therefore moves from being only nested in the interpretivist epistemology in the relativist-contextualist research paradigm to intersect with critical theory.

3.1.2. Critical theorist perspective

The second and main part of the thesis represented by papers [P3], [P4], [P5] and [P6] is more prospective in nature and includes the development of a new exhibition. This part of my work seeks to not only accumulate knowledge on the structures that shape learning environments, but also to contribute to disrupting and transforming these structures to change the status quo (Dawson, 2019; Kincheloe & McLaren, 2011). This part of the thesis is therefore situated in the critical theory paradigm in educational research (Anderson and Ellenbogen, 2012; Treagust, Won, & Duit, 2014). Anderson and Ellenbogen (2012) discuss how from a critical perspective, the cognitive domain in informal learning is not of sole interest, rather it points the inextricably and holistically linked affective, appreciative, aesthetic, moralists, motivational, social and identity domains.

Critical theory is not just one perspective, and by trying to curtail its range it loses its analytical potential (Martin, 2003). In the domain of science education research, the critical theorist seeks to understand the power relations shaping the science education content, and give voice to the underrepresented, thereby

striving to achieve an equal and democratic access to knowledge (Treagust, Won, & Duit, 2014; Anderson and Ellenbogen 2012). The critical theory stems from the Frankfurt School and the anti-fascist social critique by Horkheimer, Marcuse, Adorno and others (Agger, 1991; Lorente, 2012; Kincleloe & McLaren, 2011; Treagust, Won, & Duit, 2014). The reflections of these scholars on society has prompted branches of critical theory to appear in various fields of science.

Critical museology (Shelton, 2013) and critical theory in science education are two such branches. They share the common effort of revealing the social power structures shaping both institutions and the presented content (Anderson and Ellenbogen, 2012; Treagust, Won, & Duit, 2014). Further, they aim to give voice to the underrepresented, thereby striving to achieve an equal and democratic access to knowledge. Both branches focus on practices, however as their domains differ, they tackle different dilemmas in challenging and transforming these institutions for the betterment of the people involved (Anderson and Ellenbogen 2012; Treagust, Won, & Duit, 2014). Gender is one arena where issues of power structures is highly studied and critiqued through feminist theory.

3.1.3. Feminist theory

Feminist theory and critical theory echo each other (Martin, 2003) in that they both are critical endeavours. Disch & Hawkesworth (2016) even place feminist theory as a mode of critical theory, where, as stated by Martin (2003), they share their disruptive and deconstructive critique of what is (wrongfully) assumed to be natural conditions. Like critical theory, feminist theory is not a bounded field, a single method or static theory (Disch & Hawkesworth, 2016). Rather, it is multi-sided, multi-faceted and constantly evolving. Though feminist theory grew from the historic and cultural inequality between man and woman, the dichotomisation of concepts such as man/women, rationality/emotionality, objectivity/subjectivity, and a critique of the valuation of one over the other (e.g. Martin, 2003), it now encompasses a more general view of giving voice to the muted, empowering the repressed and changing the status quo.

My understanding of feminist theory is born in Simone de Beauvoir and her definition of 'woman' as the second sex, as the other. She describes othering, or alterity, in our community by how we cannot place ourselves as subject without also defining ourselves against the other. She describes how man experiences his body as the direct and normal link between himself and a world - a world which he believes he views objectively. This key understanding of man in regard to the world is closely linked to the understanding of the masculinity of science. Simone De Beauvoir posits that 'man' understands the 'body of the woman' as restrained by emotions and hence unable to view the world objectively. This perspective is one of the backbones of the masculinity of science, and of the positivists' persistent claim to objective 'truth'. However, Beauvoir's grouping of woman into a single entity has in the decades following her work been contested and developed. In this thesis I do not view biological sex as a unifying factor, creating two separate and distinct groups; rather, I follow the strand of postmodern (or post-structuralist) feminism. I

am thus not interested in biological signifiers or differences between woman and man. Rather, I am interested in what is symbolically associated with masculinity and femininity within our culture.

3.1.4. Gender

Following a postmodern feminist approach I view gender as not being equal to biological sex, nor an innate characteristic of an individual. My understanding of gender follows that within the field of post-modern/post-structuralist science education research (eg. Achiam and Holmegaard, 2015; Archer et al., 2016a, 2016b; Danielsson, 2009; Dawson, 2014a, 2014b; Dawson et al., 2020; Godec, 2017; Gonsalves 2018; Madsen, Holmegaard and Ulriksen, 2015). These perspectives all build on Butler's performance theory, which confronts biological assumptions and discusses how gender is in fact a social construction that we create through our performance. By performance I refer to the act of 'doing gender', in that it is enacted rather than a predetermined state (eg. Butler, 1988, 1990). Gender is performed in response to the culture, situation and context we find ourselves in. We express (and create) gender through how we dress, how we speak, how we behave and compose ourselves, and the interest, education and jobs we pursue (Gonsalves, 2018, Traxler et al., 2016). However, how we express and perform our gender is not constant over time and space; it is in other words a situated performance.

Another View

When I climb, I use my muscular intellect, in a setting where competition, power, disregard of pain, daring and rational oversight is valued and enacted by me. In this particular setting I do my gender in a way traditionally associated and stereotypically with masculinity. As I leave the gym, I put on my flowery dress, my earrings, mount my woman-style bike, and gossip with my friend over who is in love with who in the friend-group. Symbols and acts traditionally (and stereotypically) associated with femininity.

Though gender is fluid, it is not unrestricted. There are intelligible ways of performing gender, and, as Butler argues, to step outside the norm can lead to expulsion or alienation.

Furhter, what is considered the norm is situational and localised (e.g. in a science museum, an art museum, in a physics department or an anthropologist department). Gonsalves (2018) discusses how these situations form 'figured worlds' with their own often incomprehensible norms (such as socks in sandals as a signifier for an astrophysicist, (Gonsalves, 2018. p. 6)) that shape what is acceptable behaviour. Change in these figured worlds is not something that happens overnight, but by understanding the figured worlds we can begin to change them. In my project my argument is that in changing what is considered intelligible ways of engaging with astrophysics can lead to small shifts and changes in these figured worlds.

However, as Martin (2003) argues, both critical theory and feminist theory are 'better at critiquing the status quo than changing it' (p. 3). In other words, it is not action-based.
Though feminist theory, and post-modern feminism, has been, as I describe in the previous chapter, used to critique museums and museum practice (eg. Dawson, 2014a; Levin, 2010; Machin, 2008), and suggestions for *how* museums should implement feminist theory in their practice (Hein, 2010, 2011), the link and collaboration between theory and practise still lacks.

In this thesis I seek to change this, and actively link postmodern feminism and practice. I use post-modern feminist critique in understanding the status quo, but I also seek to promote change, and thus to operationalise post-modern feminism in exhibition design. However, to operationalise post-modern feminism is not by any means a simple pursuit. It has been done in prison pedagogy (Pomeroy, Holleran, & Kiam, 2004), but to my knowledge, not through design-based research in exhibition design. This projects therefore move the field forward in that it experiments with how we can use design-based research to operationalise post-modern feminism, to actively and purposefully include the voices and perspectives the *non-users.*

3.2. Design-based research

The design-based research approach allows me to both consider theory as well as practice (Bærenholdt et al., 2010; Ejersbo, 2008; MacDonald, 2007; Macdonald & Basu, 2007; Markussen, 2017) and therefore enables a operationalisation of the postmodern feminist theoretical perspective into a design process. The following section briefly outlines the general field of design research, and more specifically the field of design-based research, user involvement and theory driven design.

Design shapes our world and everyday life, and as as a consequence it inevitably shapes us. Despite of this, design research is, comparably, a young field within science. It dates back to 1960's where 'Conference on Design Methods' laid the foundation for the field (Cross, 2007). Since, three major generations regarding design research have emerged. These are summarised by Bærenholdt et al. (2010) as: research for design, research into design, and finally research through design. First, in research for design, the research is often within material, mechanism and function (Bærenholdt et al., 2010), e.g. a new foam for pillows, or teflon, as seen in space mission technologies. Second, research into design studies how the design process work, and includes theoretical framework such as phenomenology, actor-network theory and post-phenomenology (Bærenholdt et al., 2010, Cross, 1982). Finally, research through design, where research and design are interlinked. This is the framework within which this thesis is placed and this will therefore be further explored below.

3.2.1. Design-based research in educational and museum context

Design-based research sees research and design as inseparable. The design process feeds research and research feeds the design process (Cross, 1982). Put simply, design-based research is the iterative process of design, test and redesign, often exemplified by figure 6 :

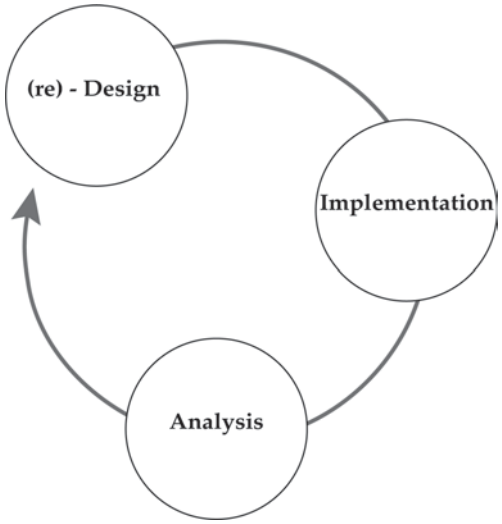


Figure 6: Simple model of the iterative design-based research process

It allows for researchers and designers (often the same person) to systemically adjust various aspects of the designed context so that each adjustment serve as an experiment which can be analysed, and through that analyses, new ideas, concepts or knowledge can be embodied in a redesign. Further, the analysis allows the researchers to test and generate theoretical insights in a practice context. Design-based research is therefore connected to experimental museology, or 'third wave' museology, where theory development is linked with systematic and iterative design experiments within the practice of exhibitions (McDonald & Basu, 2007; MacDonald 2007; Markussen 2017). Macdonald and Basu (2007) discus how experiments is a transformative process for the people as well as the materials involved. Accordingly, Macdonald and Basu (2007) argues that 'the realms of experiments and exhibitions are perhaps not so distinct'(p. 2) as both seeks to make visible the invisible (Macdonald & Basu, 2007). The particular research design in this thesis is inspired by Ejersbo et al. (2008) osmotic model and Sandoval (2004, 2014) concepts of design conjectures. The latter is described in paper [P4] as well as in the description of the design model.

3.2.2. Osmotic model base for the research design

As described above, design research involves an often cyclic process of design, enactment, analysis and redesign (Cobb et al., 2003). However, as Ejersbo et al. (2008) argue, there is a difference between the design process from the design researcher's point of view and from that of the practitioner, in this case the design company and/or museum. Where the researcher aims to build and develop theoretical insights, the practiser aims at producing a project. This difference is most evident in the analysis, evaluation and redesigning part of the process. To simplify this relationship between the researcher and design company and/or museum, Ejersbo et al., (2008) suggested the model shown in Figure 7:

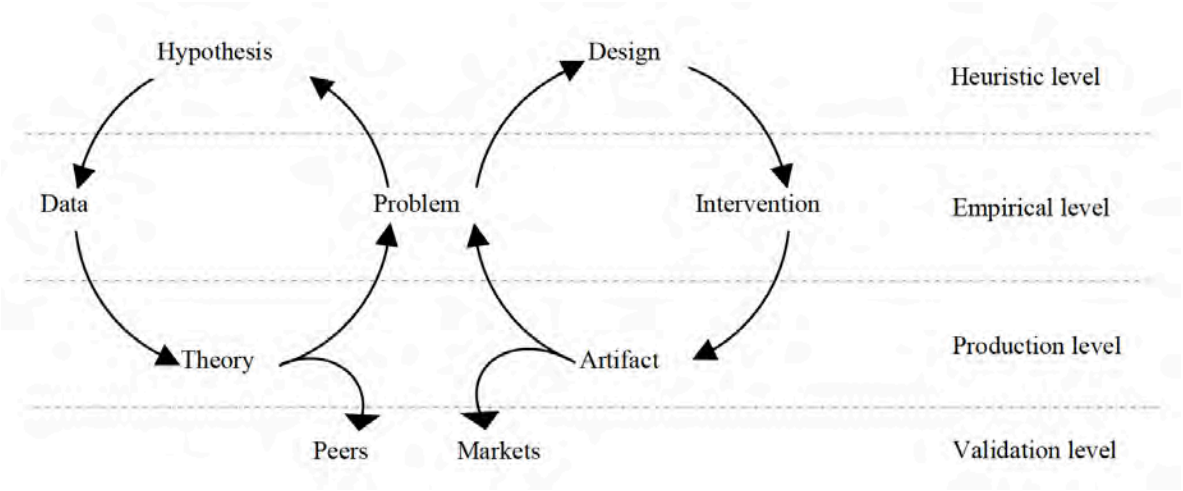


Figure 7: The Osmotic Model as presented in Ejersbo et al., (2008). This model serves as the backdrop for the development of the research design. The left circle reflects the cyclic process for the researcher, the right circle that of the design company and/or museum. The iterative process can begin anywhere in the two cycles, it can move from one to the other. The figure is further divided into four levels: the empirical level, the heuristic level, the production level and the validation level. *The empirical leve*l is often the point of departure for design process. There is an identified problem, which both practitioner and researcher want to find a solution for. *The heuristic level* is where the designers and researchers contribute with insight from the respective expertise, the moving back to the empirical level where the prototype is tested. *The production level* is where the design is executed and the theory formulated, before reaching the markets and the peers, respectively, at *the validation leve*l.

This model served as the backdrop for the development of my method and research design. This model does not explicitly include the iterative design cycles, which necessarily occur before the production level. Further, this model takes the perspectives of the researcher and the museum, but the users are only implicitly part of the model in *intervention* and *data.* Therefore, I propose a new model based on the research design of this particular study, which will be presented in the section 3.4.2. I now turn the next important perspective of the design process; the users.

3.2.3. Users perspective and involvement

The relationship between museums and their visitors has long been debated (cf. Macdonald, 2007; McPherson, 2006; Mygind et al., 2015). The evolution of how museums (and museums researchers) have viewed the public entering their museums is reflected in the vocabulary used to address them. Spectators, visitors, consumers, users, participants are terms with inherent value connotations. Connected with the words we use to describe the museum goers are how they are studied within the museum context. In this sense, understanding how museum exhibitions can influence museum goers, and to create a strict set of rules and guidelines (one size fits all) is not a new pursuit, and can be dated back to some of the earliest visitors studies within visitor/museum research (Macdonald, 2006). What has changed in the past decades is the focus on what public museums serve (e.g. Feinstein & Meshoulam, 2014). McPherson (2006) discuss the realisation that even though the visitor numbers may have increased, the social profile of who visits museums were unchanged, and the museums continues to 'favour the 'traditional' middle-class visitor' (McPherson, 2006, p. 47). Despite free entry, or 'golden tickets' a more diverse visitor profile still does not enter the museums, and the barriers is therefore more than financial (Dawson, 2019; McPherson, 2006). Thus, in defining who the visitors were, the awareness of the large group that was not included followed (McPherson, 2006). To understand this aspect museums began to think about how to involve the potential users. Consequently, both researchers and practitioners asked: If we are to discontinue the unidirectional relationship and provide more inclusive practices, how can we then begin to involve the users?

In 2010, Nina Simon discussed participatory design in a museum setting from a practice perspective. She defines participation as either contributory, collaborative, co-creative, or hosted (Simon, 2010). These show different degrees of user participation at the museum, but as Simon (2010) argues, they does not exemplify progressive steps towards an ideal practice. Rather, the most relevant degree and type of participation should be considered for projects so that they are in line with the museum's visions. This, I think, is one of the crucial points; that *how* museums arrange the design process and the type of participation is quintessential if they are to create more inclusive practices. This focus on user involvement has the potential to create a more democratised design process, and thereby more relevant and inclusive products (cf. Simon, 2010). In this thesis I use a collaborative design process. This meant that the Planetarium had set the project concept and plan, and that the Planetarium and I controlled the process, but that the users did steer the direction and content of the final product. The users are therefore collaborators in the design process, however, not co-designing it, and their participation is mediated through me to the designers.

Further, in this thesis I involve the non-users (McPherson, 20016, p.48), or potential users, as a mean of transforming them into users. I see these users as providing us with a specific perspective on a particular subject (McHardy et al., 2010). In other words, I see our interaction and understanding of the users as

snapshots of their whole person. I do not presume, that I through our interviews, grasp the full complexity, that the participants undoubtedly hold. This is further relevant when the subject of the thesis relies on feminist theory. I understand our users as being complex beings, their gender and identity as being changeable and transformative over time and in different circumstances.

I am aware of the pitfalls in the one-string approach of looking only for gender inclusion (e.g. Collins and Bilge, 2016). Ideally, when engaging in creating inclusive design approaches, one should include the many facets of social inequity. Including the complex intersection of class, gender, race, ethnicity, and ability would qualify and create a more nuanced understanding of the exclusion mechanisms that are at play (Collins and Bilge, 2016). However, in this thesis I use post-moderne feminism and gender as the prerequisite to discuss how we can represent astrophysics in a new way, so that it does not only appeal to the 'usual suspects', being those that are already interested and engage with the field. Hein (2011) argues that feminist theory can act as a vessel to address challenges of othering. As such, I follow this argument, and suggests that postmodern feminism opens a new approach to how we understand and structure the scientific content, as well as setup of the representation through design. It allows for new perspectives to be seen. Accordingly, I do not only focus on female users, as this thesis will not result in a 'female friendly design', which has been studied previously (cf. Dancu, 2010). Rather, it seeks to allow for a diverse and multiple set of voices. Consequently, I am equally interested in providing a channel through which both males and females can be heard.

3.2.4. Reflecting on the role as researcher within this process

In design-based research (Bærenholdt et al., 2010) as well as in exhibition experiments the (MacDonad and Basu, 2007) the role of the researcher and the role of the designer is often embodied in the same person. Here, however, my role was even more complex. I was insider of the group developing and designing the exhibition, in that I were a co-creator and thus had a say in the design process. However, my role was also to study the process and my colleagues, and thus my role was double-sided, as described by Adriansen and Madsen (2009). I was not employed by the Planetarium, and thus not a full insider, but I was accepted as part of the community.

As this study is placed in the critical theory paradigm, and as I do not see myself as outside the research presented in this thesis, and I am aware of the limitations and challenges linked to my role as a researcher and participant in the design process. My role was to critique as well as promote change, to challenge the design, and to implement theory. Further, my role was to be the speaker of the users, and to loyally and persistently advocate for their input to design and planetarium teams. Following this, I was then to analyse what my involvement, the implementations of theory and user collaboration meant for the design. As such, I were to analyse the subjectively generated data produced through both participation and observation, and to analyse and write through (self-)reflexive perspective (cf. Lorimer, 2007). I am thus aware of the limitations and dilemmas such an approach can hold, but argue that in order to do design-based research in the critical theoretical framework, as a researcher I can not be exempt from the design

process, and thus the researched. On this note, I now turn to how methodological considerations are combined in the research design of this thesis.

3.3. Research design

The purpose of this section is to show how the above described theoretical background and design-based research method converge to form the research design. I first give an overview of how the research questions are linked. Then, I present the design model of prospective part of this research, where postmodern feminism and the design-based research are combined. Finally, I describe the actual design process in detail.

3.3.1. Linking the research questions

As mentioned above, this project includes a retrospective and a prospective part, where the retrospective research question [RQ1] is designed to inform the prospective research questions [RQ2] and [RQ3] (see Figure 8). Thus, the results from paper [P2] are used actively in papers [P3] and [P4], which in turn are prerequisites for paper [P5]. Paper [P1] is part of the retrospective part of the thesis, and informs [P2]. Paper [P6] is not directly linked to the research behind [P1]-[P5], but it takes a point of departure in some of the thoughts and insights that matured during the project. It is prospective in that it discusses the potentials and dilemmas facing the museum world today, and how museums can address them in the future. It therefore also points to where I see my future research efforts.

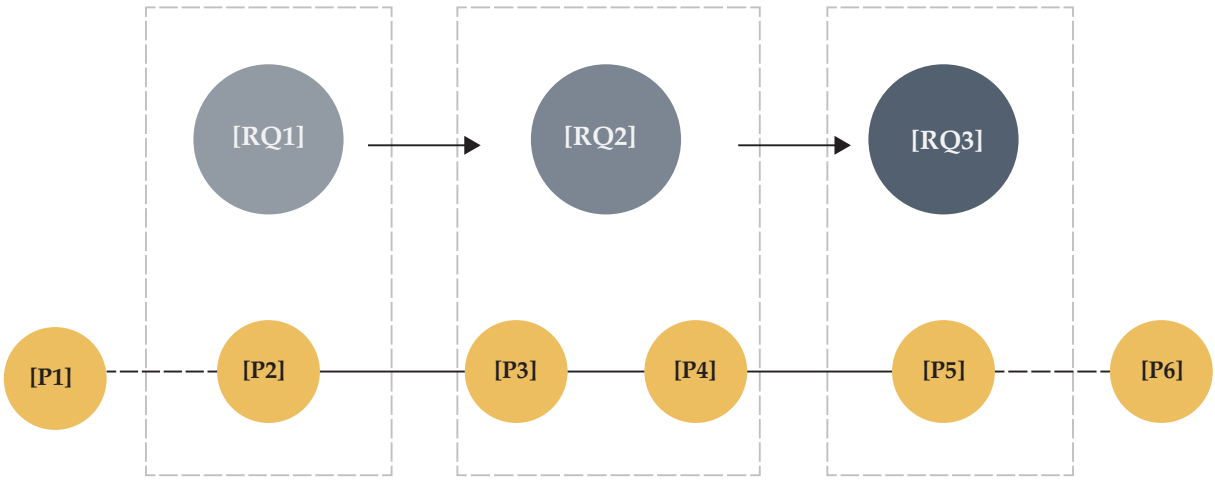


Figure 8: Schematic representation of the link between the research questions and the papers, chapter and manuscripts presented in this thesis.

The three research questions are operationalised in a definition and investigation of a problem, an active intervention, and an analysis and redefinition of the problem, leading to a re-design. Thus, the three research questions constitute the traditional (simplified) iterative process of design research as shown in figure 9:

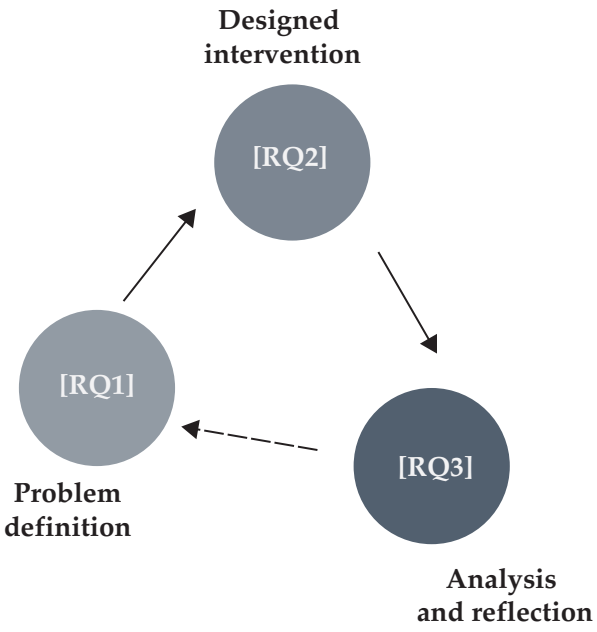


Figure 9: Illustrations of how the three research sub-questions act as a simplified design research process.

In the prospective part of the project, the insights from [RQ1] are part of the formulation of the preliminary conjectures (as described in section 3.3.4), which were then acted upon by the users in an iterative design process. Finally, as the exhibition opened to the public, I analysed the public's response to the exhibition. This analysis can then, ideally, be recirculated into a definition of a new problem, as a new starting point for the research cycle.

3.3.2. Design model

In my work, I link theory and practice through design-based research (Ejersbo et al., 2008; MacDonald & Basu 2007; MacDonald 2007; Markussen, 2017) to address a dilemma faced by modern museums (Hein, 2010). Specifically, I carry out a series of iterative design experiments as a means to create gender inequity and implement inclusive practices in exhibition design.

Figure 10 illustrates the iterative design process as it took place during the development of the exhibition. The theoretical input to the design process was drawn from postmodern feminist theory. Accordingly, I needed to 'translate' or operationalise this theory into something that could be implemented into a design process. The first step of this operationalisation was the selection of a relevant user demographic. I defined the relevant user group based on previous research that described those who are often marginalised by astrophysics (e.g. (Kewley, 2019; Primas, 2019; Venkatesan, 2019), and who were thus in risk of feeling excluded in an exhibition setting (e.g. Dawson, 2014a).

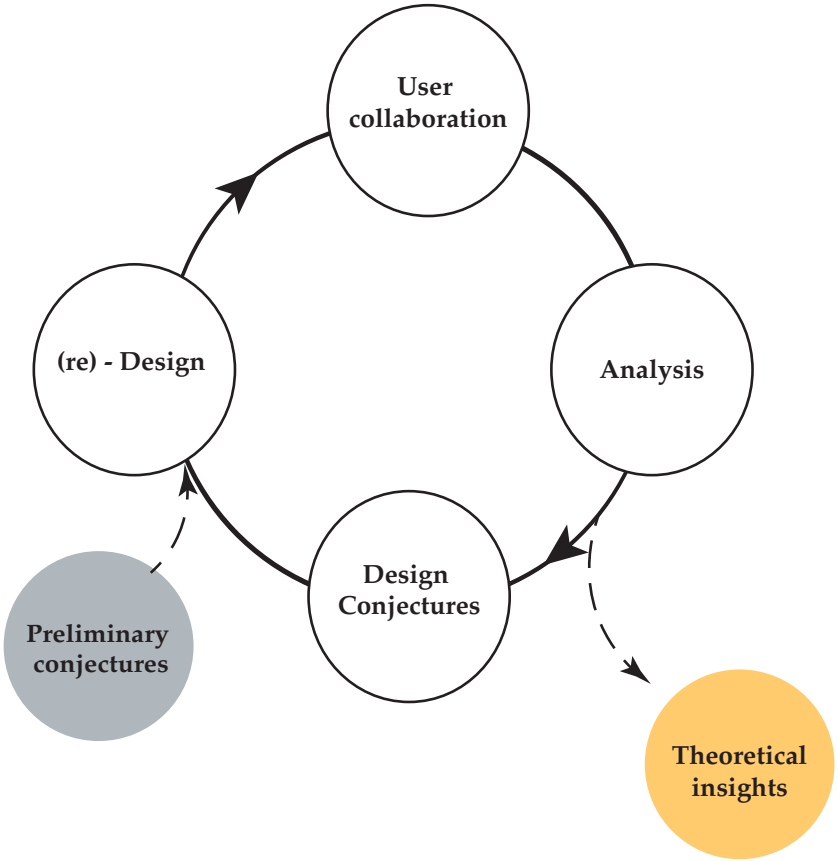


Figure 10: Model of the research design of the design process. Preliminary conjectures are formulated based in postmodern feminism, on exiting literature on inclusive education design and the findings from [P2]. These are then implemented in the design process and the development of the first design ideas. These are then tested though users collaboration, and through analysis of the users feedback, new design conjectures are formulated and implemented in the re-design. Finally, theoretical insights are derived based on the qualification of the design conjectures.

The next steps of 'translating' the theory into something which could be manifested in a design was the formulation of the preliminary design conjectures (cf. Sandoval 2004, 2014). By preliminary design conjecture I refer to the tentative ideas for design I formulated based on research on postmodern feminism (Achiam & Holmegaard, 2015, 2016; Sinnes, 2006; Sinnes and Løken, 2014), gender in education (Francis, 2000), inclusive design practices (Dancu, 2010), and the results from [P2]. In summary, these were my first conjectures about what inclusive design should include from the perspective of postmodern feminism, before any contact with the users. These preliminary conjectures are described in more detail in [P4].

Based on the preliminary design conjectures, we created the first designs (drawings, texts, schematics, illustrations), which were subsequently acted upon by the users through user collaborations, which I will describe below. I analysed the responses of the users to the designs, and created reports which then led to design conjectures, meaning a set of refined design principles that guided the re-design of the prototype, text, content, or narrative (Sandoval, 2004, 2014). The resulting products and designs were then again presented to the users, and this cyclic and interactive process occurred five times before the final exhibition

opened. In Figure #, the term 'design conjectures' thus refers to both those conjectures that are as yet untested, but also to the refined conjectures that are developed in the iterative process. The final set of conjectures are thus those that are embodied in the completed exhibition, and they are tested when Made in Space opens to the public (presented and discussed in Chapter 5).

3.3.3. The making of Made in Space

As I described when I provided background information on the Planetarium, this PhD-project commenced just as the process began to develop a new exhibition. I thus has the opportunity to be part of the development process from the beginning, and was able to influence how this process was organised. With the exhibition, the Planetarium aimed to present the newest, most cutting-edge astronomy and astrophysics research, with a focus on Danish contributions to this research. The exhibition was to become the new 'flagship' experience, and was intended to re-establish the Planetarium's role as an important out-of-school education provider.

The actors

Three main kinds of actors participated in the process of developing Made in Space: The Planetarium group, the design group and the user group. The Planetarium group consisted of the head of scientific communication, the project manager and myself. At times two additional Planetarium staff members and its CEO joined this group. The design group consisted of staff from the design company 59productions, based in London. It included the company's lead designer, a project manager, several architects, and an AV-designer. The third group was the user group, which consisted of four families. I shall return to this group in the following.

My role in this process

My role in the exhibition development process was twofold: I was tasked with contributing background knowledge from gender and science education research, and with involving, interviewing and liaising with the user group on behalf of the Planetarium and design groups.

The users

The premise of my project was to involve the non-users, meaning those demographics that did not use the Planetarium on a regular basis and, more importantly, who did not have prior interest in astrophysics and astronomy or in science. Other requirements for the selection of these non-users were the defined target group for the Planetarium and for this exhibition, namely families, and the level of difficulty for the presented content, namely so a 12-year-old would be able to understand it. Based on these requirements, and a study of how families often split into parent-child pairs in museums (Allen 2002), I defined my user groups as 'dyads', i.e. one parent and one child.

Finally, I want to briefly address one important constraint in the choice of the non-users. In my process diary (January 2016) I wrote:

> … The fact that the entrance price is high (kr) and this therefore set an inflexible barrier for who will enter Tycho Brahe Planetarium. [This is] a parameter which cannot be changed.

In other words, I saw the entry fee at the Planetarium as a constraint to defining the user group that I wanted to involve. Constraining the user group to families who were willing and able to pay the relatively high entrance fee precluded me from focusing on another important dilemma of how to include and involve publics with a variety of socio-economic backgrounds. In fact, this constraint required me to find families for whom it was a habit, or at least not unusual, to use cultural institutions, albeit not specifically the Planetarium.

It proved difficult to recruit families who were required to attend five interviews of each 1-2 hours over the course of 18 months. I managed to recruit four families, and thus had four user groups consisting of one parent and one child in the constellations of mother/daughter, mother/son, farther/daughter, father/son. Although they were few, they provided us with invaluable temporally and contextually situated knowledge on their views of astronomy and astrophysics, and their reactions to the content and its presentation. All four dyads were part of the process from the beginning to the end.

As mentioned, the dyads or users were invited to participate in five interviews (Table #). All these interviews were semi-structured (Kvale,1997, p.133). I had a rough guide for the questions I wanted to ask, as these were often related to specific steps in the design process. However, these questions were often just the starting point and as the interview and conversations progressed, I would ask follow up questions related to the focus of the users. I audio recorded the interviews and took notes. In each interview I would present the users with a design: either a concept, an object of knowledge, visualisations, a prototype or text. I would then analyse and condense their feedback, and present it to the respective Planetarium and design groups for implementation in the design.

	Content and focus
1st interview	Prior knowledge, prior museum and planetarium usage
2nd interview	Prior knowledge on atoms, feedback on introduction and Big Bang Moment
3rd interview	Feedback on design scheme and text
4th interview	Feedback on prototypes
5th interview	Feedback on final design

Table1: Presentation of content and focus of the interviews and user collaboration.

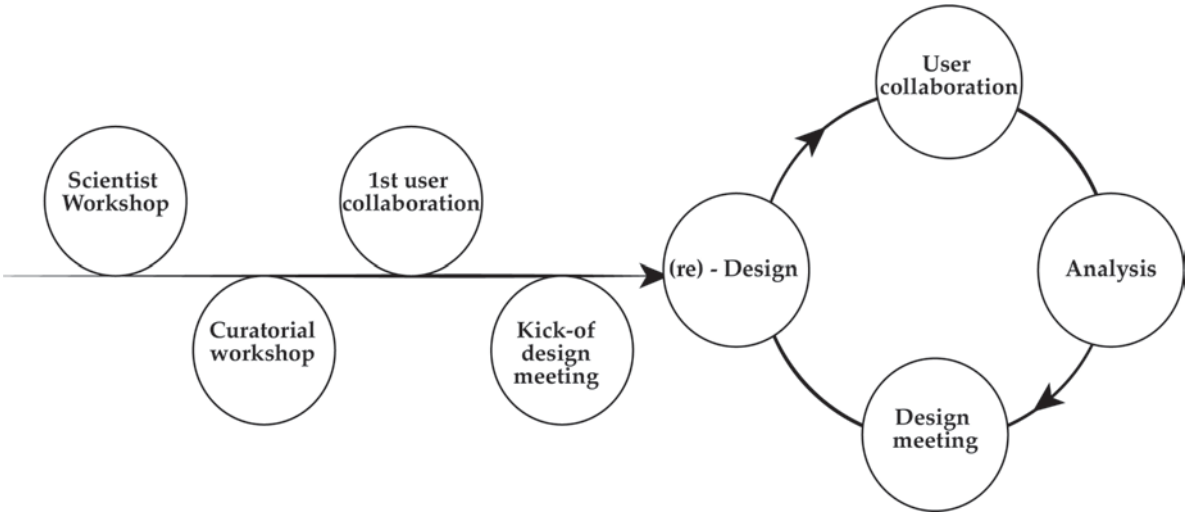


Figure 11: Simplified illustration of the steps in the design process.

Ethical considerations

The users who took part in the development process as well as the participants involved in the final analysis of the exhibition (Chapter 5 [P5]) were made aware of the general frame of the research. I informed them that I was not an employee of the Planetarium, but of the University of Copenhagen. They were informed that their participation was voluntary, and that they could withdraw from the research at any point without having to provide an explanation. This study did not involve vulnerable adults or children, but as the younger halves of the dyads were under the age of 18, I sought their parents' consent as well as their own. I asked them for permission to record the interviews and to take notes, and informed them that I would use these records to recall the interview, as well as to provide anonymised feedback to the Planetarium and design group and data for my research articles. I respected the anonymity and privacy of research participants as well as assuring data confidentiality. To protect the participants, all of the names of the participants were anonymised at the point of transcription. When presenting the feedback from the users to the Planetarium and design group, the users were anonymised, and all person-specific data is deleted.

The practical steps in the process

The development process was organised in bi-weekly exhibition meetings, where the head of scientific communication, a project manager, and myself. When relevant, the CEO of the Planetarium was part of these meetings. In these meetings we discussed the forthcoming tasks, made strategic decisions, and discussed content and design. I was thus an active participant in the process.

As mentioned in the preceding, design-based research takes place in alternating prospective and retrospective phases. In the present case the prospective part of designing Made in Space had a 'what' phase and a 'how' phase (a simplified representation of the 'fuzzy-design' process is presented in figure #). The first phase was deciding 'what' to be presented, and took place in two workshops, the scientist workshop

and the curatorial brief workshop, which are described and analysed in [P3] and [P4]. In the scientific workshop, researchers at the cutting edge of astrophysics research in Denmark were invited. These professionals were tasked with identifying the most important recent astrophysics research in Denmark. This resulted in a list of topics, which was then rearranged during the curatorial brief workshop (discussed in [P3]).

The following 'how' phase consisted of deciding 'how' to present the selected content. It included interviews with the users and meetings and workshops with potential designers. Specifically, meetings were held with three design firms, who were made aware of my involvement as a researcher in the process and that this would mean that they were to incorporate the preliminary design conjectures as well as the feedback from the users. The company 59productions was chosen to design the exhibition in part because they had included in their 'pitch' ideas about how to collaborate with me as a researcher, and because they were open and interested in the project from the beginning. This point seems superfluous, but turned out to be highly relevant for the project, as the collaboration with me most certainly meant more work for them, while being essential to the success of the project.

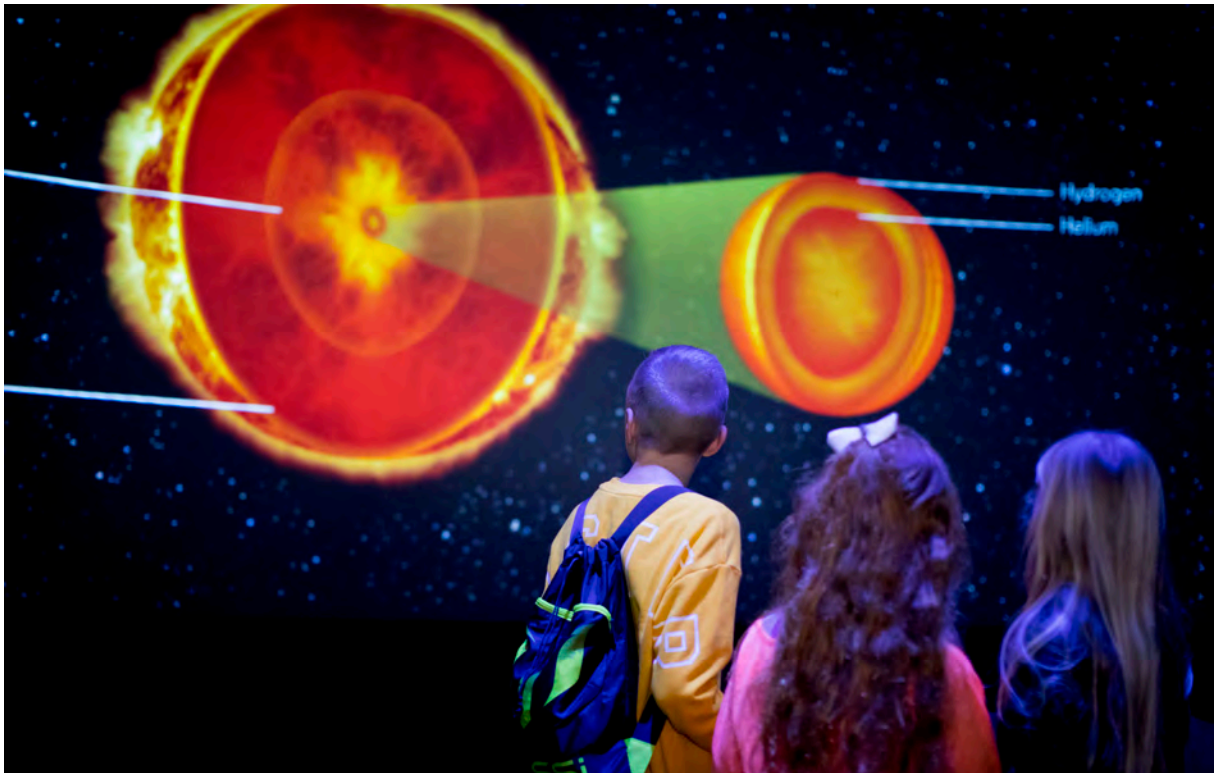
The first workshop of the 'how' phase was the 'kick-off'-design workshop. This workshop is important to mention, as this was the first time all members of the design group and the Planetarium group met. Further, it was during this workshop that I presented the concept of inclusion, as well as insights from the first round of user interviews. In [P4] I describe how these preliminary design conjectures came to inform the design of the exhibition.

The subsequent design workshops and research meetings were essential steps in the process. In the workshops all members of the design and Planetarium groups met. Here, we were presented with prototypes and design ideas, I presented the most recent feedback from the users, and we discussed how to implement this feedback in the following design. The actors in design meetings were typically the head of scientific communication, the lead designer from 59productions and myself. During these meetings we discussed the content in detail, where the head of scientific communication provided the scientific astrophysics knowledge and I gave recommendations based predominantly on the users' feedback, but also on what I learned from my ongoing reading on inclusive practices with the lens of postmodern feminism.

The final steps of the 'how' phase occurred when the exhibition was being installed. Here, the user feedback gave insights into more the technical and detail-oriented aspects of specific interactive exhibits, and the final feedback was incorporated by the designers and technicians. The exhibition opened the 1st of February, 2018

3.3.4. Made in Space

To present an exhibition experience in 2D is difficult. However, below I present four photos to give a small illustration of the final exhibition. The four chosen pictures show key elements of the exhibition (Figure 12 and 13).



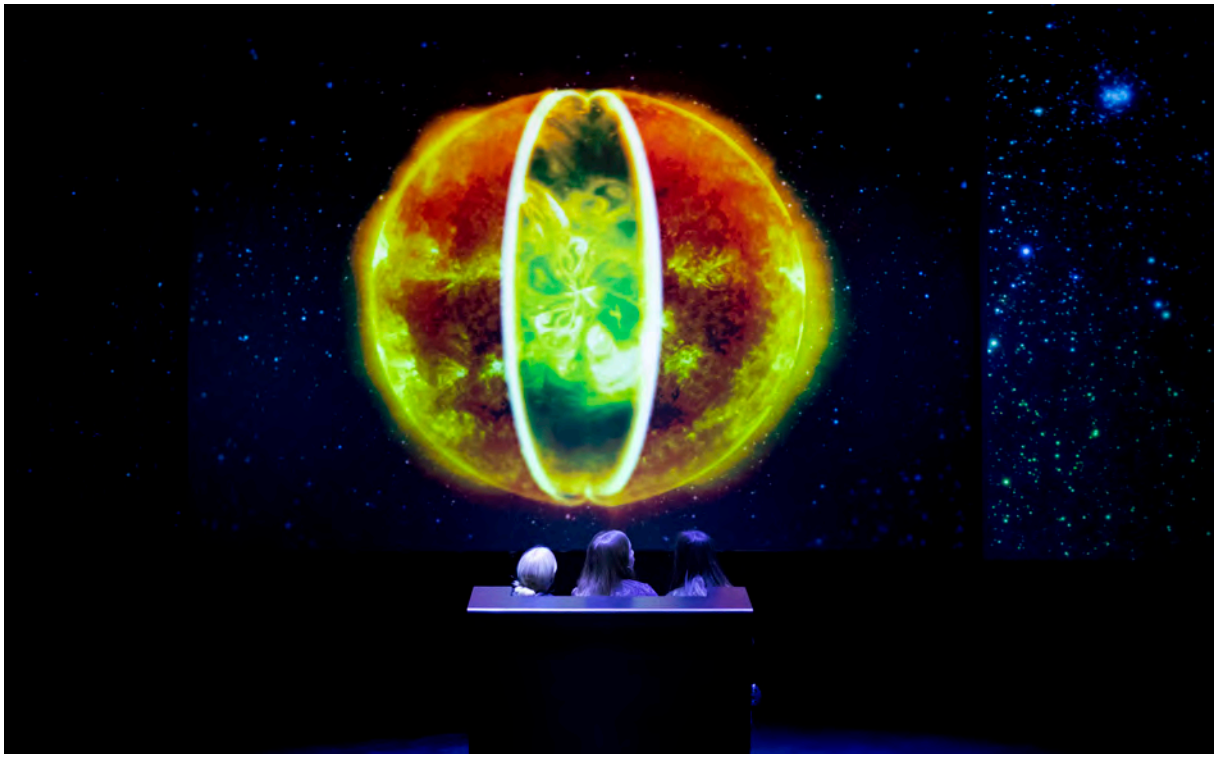


Figure 12: Photo of 'Small and Medium Sized Stars' projection screen (above), and 'Supernova' exhibit, showing a visualisation of a supernova explosion. Photo: *Planetarium*

Figure 13: photo of the ‘Star Formation’(above) interactive on the ground, which allows the users to generate a gravity field and thereby form stars. Below are the ‘Big Bang Moment’ (colours misrepresented). Photo: *Planetarium*


PART 4

4. The Contributing Articles

[P1] **Paper 1:** Planetariums between experience and enlightenment (Nordisk Museologi, published)

[P2] **Paper 2:** The Implied Visitor in a planetarium exhibition (Museum Management and Curatorship, Published)

[P3] **Paper 3:** 'We are part of the Universe, the Universe is part of us':Transforming the astrophysics in the Planetarium (accepted for publication)

[P4] **Paper 4:** Made in Space: Operationalising post-modern feminism in exhibition design (manuscript)

[P5] **Chapter 5:** Final analysis of 'Made in Space'

[P6] **Paper 6:** Museums beyond Neutrality (in review)

4.1. [P1] Planetariums between experience and enlightenment

This first paper is placed in the retrospective part of the thesis. It answers the research question of how present-day Scandinavian planetarium education professionals perceive the relationship between enlightenment and experience, with respect to their dome programmes, and what the implications of this perception are for planetarium practice. It is written as a contribution to the 'Our Museum' research programme, and therefore addresses the common aim and research agenda of the programme (see 1.2 and 1.2.1). This paper informs the following research in this thesis by taking the perspective of the practitioners and their view on practice. The insights that stem from this paper were that educational professionals view enlightenment and experience as being two complementary aspects of their dome programs, as well as in relation to their dissemination and communication practice. Thus, they see a connection between the cognitive and aesthetic aspects in presenting astrophysics. The paper therefore suggests that planetariums can benefit from embracing this complementary relationship between enlightenment and experience. Further, that the affective, emotional, spectacular aspects and potentials of astrophysics could be effective in promoting a more literate citizenship. This viewpoint is a common thread throughout the thesis.

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Planetariums between experience and enlightenment

Marianne Achiam, Line Bruun Nicolaisen & Tina Ibsen

Abstract: *Planetariums are committed to promoting public knowledge about astronomy and space. At the same time, they have a legacy of offering spectacular and immersive experiences in their dome programmes. These outcomes do not always sit comfortably together; in fact, international research shows that many planetarium staff members consider experience and enlightenment to be mutually exclusive. In this study, we develop the argument that enlightenment and experience do not necessarily contradict each other in the planetarium context. We survey staff members from Scandinavian planetariums on their perspectives of planetarium dome programmes, and show that here, enlightenment and experience are considered to be complementary in successful planetarium dome dissemination. We discuss these findings and offer our reflections on their implications for the practice of planetariums.*

Keywords: Science education, didactics, science centres, museum professionals, learning.

Since the emergence of the first dome-shaped projection planetariums in Europe and the United States in the early twentieth century, scholars have discussed whether the essential effect of the planetarium is in the cognitive or the affective domain (Smith 1974, Sunal 1976). These discussions should be seen against different cultural backdrops: In the United States, the Sputnik Shock in 1957 resulted in a proliferation of projection planetariums as parts of a larger infrastructure to support the development of a scientifically literate public (Slater & Tatge 2017). Many American planetariums were thus primarily associated with primary, secondary or tertiary education institutions; a focus that seemed to permeate or even trump discussions of the more immersive or aesthetic aspects of the planetarium, as illustrated in the following statement made by planetarium director Dr Charles Henry King in 1966:

> Give [the public] what they want – entertainment, thrills, and means of escape from the cares and worries of the "world outside." Provide excitement, drama, and spectacle. Let them see the sun, moon, and planets career across the sky. [...] In brief, do anything that will help conceal the unpleasant truth

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> that a planetarium is primarily an educational device and is, or should be, concerned with astronomy (King 1966, cited in Griffiths 2008:132).

In contrast, in the early twentieth century, European projection planetariums were acknowledged not just in the contexts of science and education, but also in the contexts of performance and aesthetics (Wolfschmidt 2007). These cultural institutions were considered to be "theatres of the stars" located at the intersection of science, technology and spectacle (Bigg & Vanhoutte 2017). Indeed, the sensory nature of the planetarium was not seen as antithetical to education, but rather, as well-suited to contemporary object- and experience-based pedagogies (e.g. Deinhardt 1934). Sensory experience and imagination were seen as appropriate pathways to learning (Bigg 2017).

In spite of their different cultural settings, European and American planetariums also had similarities. Towards the end of the twentieth century, planetarium technology across the western hemisphere had progressed to the point where it was possible to immerse visitors in virtual space-travel: Planetarium-goers could now travel to the Moon, planet Mars, or beyond (Backhus 2013). More and more, the planetarium dome became a *performative* space (Griffiths 2008; Vanhoutte & Bigg 2014) in which visitors could see the universe from places no human can go, in ways that are inaccessible to human perception (Eriksson 2014). The gradual evolution of this basic planetarium characteristic, in which technology mediates that which lies beyond human perception, and immerses visitors in what it "is like" in space (Bleeker 2017), seems to imply that in modern digital planetarium domes, there cannot be education without experience.

Even so, many present-day accounts of planetariums from both Europe and the United States seem to view the educational and the spectacular as two ends of a spectrum, or even mutually exclusive (Croft 2008). For instance, in his reflections on the prospective new planetarium in Strasbourg, Soubiran (2017) points to tensions between scientific and spectacular astronomy, between education and entertainment, and between pedagogy and wonder. Backhus (2013) discusses how, in US planetariums, the objectives of education and entertainment are described as counterparts. Finally, in a study of planetarium education professionals, Croft (2008:17) observes how they "struggle[d] to make complex scientific concepts understandable to their audiences within the aesthetic medium [of the dome programme]". Similar dichotomous perceptions are present among planetarium education professionals studied by Littmann (2009) and Plummer & Small (2013).

To summarise, in spite of what we might describe as the fundamental immersive performativity of the modern planetarium dome in which education and aesthetic experience are inextricably linked, we observe a dichotomisation in recent history between the notion of the planetarium dome as a milieu that promotes scientific knowledge, and the notion of the dome as a milieu that offers more sensory experiences of space. From a museological perspective, this relationship seems recognisable as the more general distinction between the Enlightenment ideal of providing public education and the more consumer-oriented ideal of offering entertaining experiences (Anderson 2004, Black 2012). In the following, we thus use the terms *enlightenment* and *experience* to signify these two characteristics of planetarium dome programmes (table 1).

Enlightenment	vs.	Experience	Reference
cognitive	vs.	affective	Smith (1974)
didactic	vs.	aesthetic	Wolfschmidt (2007)
scientific	vs.	aesthetic	Croft (2008)
science	vs.	spectacle	Griffiths (2008)
education	vs.	entertainment	Backhus (2013)
pedagogy	vs.	wonder	Soubiran (2017)

Table 1. Examples of dichotomous terms used by planetarium practitioners and researchers to describe tensions related to planetarium dome dissemination programmes, summarised here as "enlightenment" and "experience", respectively.

We formulate our research question in the following way: How do present-day, Scandinavian planetarium education professionals perceive the relationship between enlightenment and experience with respect to their dome programmes, and what are the implications of this perception for planetarium practice? In the following sections, we develop our methodological perspective and explain our data collection and analysis procedures.

Methodology

We approach our research question from what Anderson and Ellenbogen (2012) designate as a *relativist–contextualist* research paradigm. This means that rather than searching for an objective, generalisable "truth", we focus on the localised and subjective meanings of human experience (cf. Treagust, Won & Duit 2014). We see educational environments such as planetarium dome programmes as rich and complex phenomena, and we attempt to capture planetarium professionals' perceptions of this complexity using qualitative and interpretivist methods.

Our study consisted of three main phases. In the first phase, we collected and studied the research on planetarium dissemination, educators, and dome programmes referenced in the preceding. In our group, which consisted of two university researchers and one planetarium professional, discussions of these texts served not only to establish and validate the problem at stake, but also to make the dimensions of enlightenment and experience recognisable and meaningful from perspectives of both practice and research.

In the second phase, we constructed an online questionnaire in Google Forms (see Appendix) to gather data from planetarium education professionals in the Scandinavian countries. In addition to a set of closed-ended demographic questions, we developed a set of multiple-choice questions to uncover the connotations of the terms enlightenment and experience among respondents. Further, we developed a number of open-ended questions about respondents' specific perceptions of enlightenment and experience in relation to their individual dome programmes. In particular, the open-ended questions were an attempt to gain access to the rich verbal descriptions that characterise research in the

14 relativist–contextualist paradigm (Treagust, Won & Duit 2014).

In the third phase, we collected, analysed, and discussed responses from planetarium education professionals. In this phase, we carefully scrutinised the data to "crystallise" strong and valid images of respondents' lived experiences (Denzin & Lincoln 2011). The specific procedures are described in detail in the following section; the third phase was concluded with the reporting of our study (the present text). In this reporting, we attempt to provide a detailed narrative of our procedures and findings (Treagust, Won & Duit 2014).

Data collection and analysis

In the autumn of 2018, we distributed the online questionnaire to planetarium professionals from institutions that were members of the Nordic Planetarium Association (NPA) and located in Sweden, Denmark, and Norway. The questionnaire was distributed through several channels: The NPA newsletter, the NPA's pages on social media channels Facebook and Slack, and by direct email to all members that attended the bi-annual NPA meeting in 2017. The questionnaire was distributed to 45 NPA members, and 13 (or 29 percent) responded.

The questionnaire had two sections. The first section inquired about respondents' own views on their planetarium programmes, whereas the second introduced the notions of experience and enlightenment. The respondents were not able to view the second section before they had responded to the first. They were thus not aware of the experience/enlightenment theme of the questionnaire when they responded to the first section, and their initial answers were presumably not prompted or guided by this theme.

Multiple choice questions

We developed the multiple-choice questions in our questionnaire to understand what connotations the two terms enlightenment and experience held for our respondents. To this end, we constructed a list of twelve phrases that reflected different aspects of dissemination, and asked respondents to indicate which of these terms they associated with enlightenment, with experience, with both, or with none. We assumed that if enlightenment and experience were perceived as mutually exclusive, the responses would show a clear bimodal distribution, whereas if enlightenment and experience were seen as being related, many of the twelve phrases would be associated with both enlightenment and experience.

We mapped the responses with the network visualisation software Gephi, using the Force Atlas layout. In this layout, "nodes" physically repulse each other, while connections between nodes attract them to one another, as if they were connected by springs (Jacomy *et al.* 2014). In the resulting network, the physical proximity of the twelve "phrase" nodes to the enlightenment and experience nodes thus represents the degree to which they are attracted to (i.e. associated with) enlightenment and experience, respectively.

Open-ended questions

We formulated two essential, open-ended questions to explore the planetarium professionals' perceptions of experience and enlightenment with respect to their individual dome programmes. We were interested in obtaining their own phrasing and wordings to uncover their perspectives on their dome programmes.

The first open-ended question asked respondents to describe the most important

goal for their planetarium dome programmes. As mentioned, this question was posed before the respondents were introduced to the notions of experience and enlightenment in the questionnaire. In the second open-ended question, the planetarium professionals were asked to give an example from their dome programme that illustrates the relationship they describe between experience and enlightenment. This question was posed after the multiple-choice questions described in the preceding, where respondents were prompted to indicate their perceptions of the notions of experience and enlightenment and the relationships between the two notions. We analysed the data resulting from the open-ended questions using the six-step thematic analysis method described by Braun and Clarke (2006).

Results

Thirteen planetarium professionals responded to the questionnaire; of these, five were from Denmark, five were from Sweden, and three were from Norway. In the following, the responding professionals are designated as Respondent 1 through 13.

Objectives of planetarium dome programmes

When describing the primary goals of their planetarium dome programmes, planetarium professionals overwhelmingly used terms reflecting affective or aesthetic processes, as illustrated by the following responses:

Respondent 2: Stimulating the curiosity and sense of wonder
Respondent 8: To provide an experience that piques the visitor's curiosity
Respondent 9: To give the visitors a taste of space

Some respondents used terms that had educational or scientific aspects; however, these terms were always juxtaposed with terms associated with affective or aesthetic processes:

Respondent 1: Education, inspiration, encouragement to seek higher education
Respondent 5: A nice experience where a bit of science and/or natural history is included
Respondent 12: Edutainment (Education and Entertainment)

These responses indicate that while the primary objective of planetarium dome programmes may be related to lived aesthetic or affective processes, such processes are not necessarily perceived to be in opposition to education or learning about science. Indeed, the planetarium professionals' responses to the multiple-choice questions (presented in the following) support this conjecture.

Relationship between experience and enlightenment

Among the responding planetarium professionals, there seemed to be a collective sense that experience and enlightenment were related to each other in a number of ways (fig. 1). Although some phrases were more strongly associated with experience (e.g. "sensing", "feeling", or "enjoying") and others were more strongly associated with enlightenment (e.g. "education", "thinking" or "understanding"), none of the phrases were exclusively associated with one term or the other. In particular, the phrase "learning" was strongly associated with both enlightenment and experience by the respondents.

Accordingly, we interpret the data visualised in figure 1 to mean that planetarium professionals do not have a dichotomous perception

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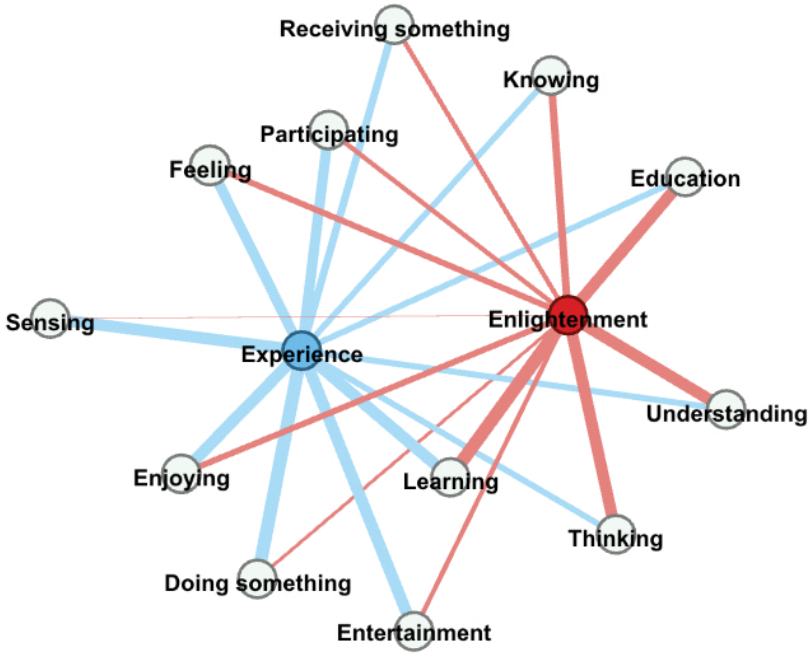

Fig. 1. Visualisation of planetarium professionals' associations of the terms experience (blue node) and enlightenment (red node) with twelve phrases related to dissemination (white nodes). The width of the connecting lines indicates the number of instances in which two nodes were connected.

of enlightenment and experience, but rather, that the two are perceived to be connected. In the following section, we present data to further support and elaborate this conjecture.

Experience and enlightenment in planetarium dome programmes

When asked specifically about the interconnectedness of enlightenment and experience in planetarium dome dissemination, all responding planetarium professionals affirmed that "Dome programmes can focus on the visitor's enlightenment and their experience at the same time. A programme that is enlightening is also experiential, and vice versa". Finally, when asked to exemplify this association with a point of departure in their own dome programmes, a correlation between the notions emerged, as illustrated in the following:

Respondent 3: The guest has a sensory experience with the vastness of space, and I hope this gives them an enlightened feeling of the same.

Respondent 7: When using the digital universe system, travelling around between planets is an overwhelming experience. When we at the same time teach the audience about the planets, you get enlightenment and experience at the same time.

Respondent 11: The aim [of our dome show]

> is to involve, intrigue and inspire the audience and in the process potentially allow them to access previously unknown concepts and ideas.

Our interpretation of the planetarium professionals' responses is that they consider the relationship between enlightenment and experience to be complementary or even causal, in other words that experience is seen by planetarium professionals as the *means* to reach the ultimate *end* of enlightenment. We shall return to this interpretation in the discussion.

Summary of results

The planetarium professionals' responses to the questionnaire seemed to follow parallel trajectories wherein the majority initially associated their dome programmes with aesthetic experience, while some additionally associated the programmes with more scientific, knowledge-acquisition outcomes. When prompted, all respondents observed that enlightenment and experience can and do co-exist in planetarium dome programmes. Finally, in their reflections about how the two co-exist in their own dome programmes, the planetarium professionals indicate a correlation or even causality between them: experience can lead to enlightenment.

Discussion

In the present study, we set out to understand the ways in which Scandinavian planetarium education professionals perceive the relationship between enlightenment and experience with respect to their dome programmes, and to explore the implications of these perceptions for planetarium practice. Our primary result – that experience and enlightenment are perceived as complementary and perhaps even as having a causal relationship – contrasts with the perceptions of (non-Scandinavian) planetarium professionals published in the literature; yet, as we discussed in the introduction, is perhaps not surprising given the immersive performativity of the planetarium dome. In the following, we briefly discuss some limitations of this study. We then proceed to considering possible reasons for the divergence of perception between planetarium professionals in international studies and in the Scandinavian case. We finally offer our thoughts on the implications of our findings for planetarium practice.

Limitations of this study

Our empirical material consists of responses from just 13 planetarium professionals, with considerable variation in length. Ideally, these written responses would have been explored through, for instance, qualitative interviews (cf. Treagust, Won & Duit 2014); however, this was beyond the scope of the work carried out here. The evident limitations of our dataset are further compounded by the fact that we, in our initial search for literature on planetarium professionals and dome programmes, were not able to locate any studies carried out in Scandinavian or Nordic contexts. Taken together, this means that we have difficulty assessing how much our findings can be generalised across the Scandinavian context.

The lack of Scandinavian or Nordic planetarium studies also means that we don't have a strong sense of the extent to which our findings are in fact an indicator that Scandinavian planetarium practice differs from that of other planetariums. In the following, we provide possible explanations for our findings, but we cannot rule out that the particular construction of our questionnaire

18 was what prompted responses that differed from those published in the literature. Thus, one explanation for the divergence between international and Scandinavian planetarium professionals with respect to enlightenment and experience is that our methodology prompted the differences. We attempted to avoid this issue by asking open-ended questions with free-text answers, thus allowing respondents to phrase their own understandings, but we cannot be sure that we didn't inadvertently cause the divergence. However, in the following we proceed on the assumption that this was not the case.

Diverging perceptions of enlightenment and experience in planetariums

Planetarium dome programmes are what Griffiths (2008:116) calls *intermedial* events, in the sense that they combine spectacular display techniques with scientific performance. We have argued that this means that it is difficult or even impossible to separate their experiential aspects from their enlightenment-related ones. Why, then, do we find so many examples in the literature of planetarium professionals who struggle to reconcile those two aspects?

One possible answer to this question may be based in ideology. The traditional Enlightenment model of science is one of reason, neutral rationality, and dispassion; these characteristics have also permeated the present-day domain of public communication and engagement in science (Elam & Bertilsson 2003). This means that many efforts to engage the public in science have tended to ignore the non-discursive aspects of science such as materiality, embodiment and affect (Davies 2014). In this light, perhaps it is no wonder that many planetarium professionals find the experiential aspects of the planetarium dome programmes difficult to reconcile with their scientific ambitions. But why do *Scandinavian* planetarium professionals seemingly have a different perspective?

The case of Scandinavian planetariums

Cultural institutions such as planetariums do not exist in a vacuum, but are part of the societies that surround them (Kreps 2006). This means that their practices are shaped not only by their specific institutional cultures, but also by the socio-cultural systems they exist within (Achiam & Marandino 2014). When we consider the perceptions of education professionals in Scandinavian planetariums, we should therefore consider not only what it means to be a planetarium, but also what it means to be Scandinavian. In this context, the Nordic model of education offers one possible explanation for the particular perceptions of Scandinavian planetarium professionals, and their divergence from those of other planetarium professionals.

The Nordic model of education, founded in the years following the Second World War, focuses on promoting not just scientific knowledge but also personal growth (Telhaug, Mediås & Aasen 2006). Especially in the Scandinavian subsets of this model, the emphasis is equally on cognitive, affective, and skills development, and learning is perceived to involve experience that is acted and reflected on by the learner (Kanuka 2015). If we zoom in on the case of *science* education, we again find a shared Scandinavian perspective that echoes these characteristics, emphasising the role of the cultural, aesthetic and affective aspects of science for education (Andersen *et al.* 2004).

Accordingly, we suggest that one way to explain our results is in terms of this shared Scandinavian perception of (science) education as involving not only cognitive components, but also aesthetic and affective components;

in other words, both enlightenment and experience. Even though planetariums and their dome programmes share their genealogy with similar institutions around the world, the specific cultural setting of the Scandinavian planetariums studied here thus seems to entail an encoding of the planetarium dome programmes in terms of the particular Scandinavian ways of seeing, valuing, ascribing meaning to and treating scientific practices (cf. Achiam & Marandino 2019).

Of course, the explanation we offer here is speculative, and warrants further examination. An alternative hypothesis might reasonably situate Scandinavian planetariums within the larger European planetarium community, and thus explain the divergence in terms of the different historical contexts for American and European planetariums (as briefly outlined in the introduction). Due to the patchy and heterogenous nature of research on planetariums before 1990 (Slater & Tatge 2017), this hypothesis would require a careful and in-depth historical synthesis of findings from both sides of the North Atlantic. We hope to able to provide such a synthesis in the future.

Implications for planetarium practice

For planetariums, an acknowledgement of the complementary (or even causal) relationship between experience and enlightenment may have particular significance. We have already discussed how the Enlightenment ideal tends to disregard aspects of science such as materiality, embodiment and affect. This phenomenon may be even more pronounced with respect to the planetarium disciplines astrophysics, cosmology and space technology, which are framed as rational, abstract, objective, difficult and elitist (Due 2014). As a result, they tend to attract and include only those individuals whose identities fit comfortably with such characteristics (Danielsson 2012; Leslie *et al.* 2015). What this means is that if and when planetariums more fully and explicitly embrace the experiential, aesthetic and embodied aspects of astrophysics, cosmology and space technology as well as the abstract and rational aspects, those planetariums are offering their visitors a more nuanced representation of these disciplines, as well as a more welcoming and inclusive one (cf. Bracey 2017).

Another important implication of embracing both the enlightenment and the experience aspects of the planetarium disciplines is related to the larger cultural and societal discussion of the benefit to humanity of space technology and exploration. Griffin (2014) discusses how space agencies such as ESA and NASA employ a positivist discourse in their outreach activities that positions these benefits as universal and self-evident, disregarding or even diminishing members of the public who do not comprehend or agree with them. Here, Griffin argues, there is a role for the 'affective space' that is produced along with space technology and spacefaring, because large parts of these disciplines can only be accessed through their imaginaries (Griffin 2014). In other words, planetariums are well positioned to contribute to a deeper public discussion of the benefits of exploring and understanding space by engaging their visitors in more holistic experiences of these disciplines.

Final words

We would argue that planetarium professionals worldwide could benefit from embracing the spectacular, embodied, indeed experiential aspects of the dome programme in their considerations of its enlightenment potential. As Bigg & Vanhoutte (2017:116) observe, "the spectacularisation of the 'hard'

sciences has been under-theorised", yet this spectacularisation could have an important role to play in creating a scientifically literate citizenship. Institutions such as planetariums have the unique potential to offer the public symbolic experiences that transcend time and place (Achiam 2016); such experiences, we would argue, are as much a part of science as the dispassionate reasoning of the Enlightenment ideal. Although the present study has probably raised more questions than it has answered, we hope that it will spark new discussions about planetariums and their larger educational and cultural role in contemporary society.

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Appendix

The questions from the online Google Forms questionnaire distributed to planetarium education professionals.

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Planetarium Dissemination in the Dome

This survey is about the dissemination of astronomy, space travel and related subjects that is carried out using the planetarium dome in your planetarium. We are interested in programmes, with or without live presentations by planetarium professionals, that include the projection of images on the dome surface. For this survey, please answer based on the programmes your planetarium offers to casual visitors, i.e. not those for school groups (unless they are the same)!

Section 1: About you and your planetarium

Where is your planetarium located?

☐ *Denmark*

☐ *Norway*

☐ *Sweden*

Thinking about yourself as a planetarium professional, is your educational background more strongly linked to science or to education?

☐ *Science (e.g. astronomy, physics, natural sciences, engineering, technology, etc.)*

☐ *Education (e.g. pedagogy, psychology, education studies, teacher professional development, etc.)*

☐ *Other: [Long answer textbox]*

In your opinion, what is the most important goal for your planetarium's dome programmes (for casual visitors, not schools)?

[Long answer textbox]

Section 2: Your general ideas about 'enlightenment' and 'experience'

We are interested in your ideas about the terms 'enlightenment' and 'experience', and what they mean to you.

Please indicate which words you associate with the two terms. You can check two, one or no boxes in each row.

	Enlightenment	*Experience*
1. Doing something	☐	☐
2. Receiving something	☐	☐
3. Thinking	☐	☐
4. Entertainment	☐	☐
5. Participating	☐	☐
6. Learning	☐	☐

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7. Knowing	☐	☐
8. Feeling	☐	☐
9. Sensing	☐	☐
10. Education	☐	☐
11. Enjoying	☐	☐
12. Understanding	☐	☐

The relationship between 'enlightenment' and 'experience'

Internationally, among planetarium dissemination professionals, there are two main perspectives. One perspective is that planetarium dome programmes can be focused on the visitors' enlightenment OR their experience, but that programmes cannot focus on both at the same time. This means that programmes that are enlightening cannot be experiential at the same time, and vice versa.

The other perspective is that enlightenment and experience CAN and DO go hand in hand in planetarium dissemination. This means that a programme that is experiential is also enlightening, and vice versa.

Which idea do you agree the most with?

☐ *Dome programmes can focus on the visitor's enlightenment OR their experience, but not both at the same time.*

☐ *Dome programmes can focus on the visitor's enlightenment and their experience at the same time. A programme that is enlightening is also experiential, and vice versa.*

☐ *Other [Long answer textbox]*

Please give an example from a dome programme at your planetarium that illustrates the relationship between enlightenment and experience that you indicated above. Please describe in detail how the relationship between enlightenment and experience is manifested in the example.

[Long answer textbox]

If you have questions or comments about this survey, please type them below.

[Long answer textbox]

Thank you very much. If we may contact you for follow-up questions, please type your e-mail address in the box.

[Short answer textbox]

4.2. [P2] The Implied Visitor in a planetarium exhibition

The second paper [P2], is the first to focus on the research case and collaborator, the Planetarium. It is placed in the retrospective part of the project and answers the first sub- research question:

> RQ1: How do present-day planetaria, science centres and museums present astronomy and astrophysics in exhibitions, and what are the implications of these exhibition designs for the gender inclusion of the visitors?

In this paper, we are interested in understanding how the planetarium educational professionals previously have presented astrophysics, space technology and planetary science within this particular planetarium, in order to establish its previous practice. Further, we were interested in who was the 'implied visitor' in this context, and to what extent gendered structures (as described previously), were embodied in the design and arrangement of the exhibition titled Space Mission. This paper therefore serves as the definition and investigation of the problem in the research design process. We find that the masculine gendering of the implied visitor may hinder inclusion of visitors across the gender spectrum, and this paper thus serves as an argument for the need to address and challenge the dominant discourses within astrophysics. This paper is therefore a prerequisite for the following papers, where this problem is addressed through the design-based research process.

Status: Published in a level 2 ranked journal

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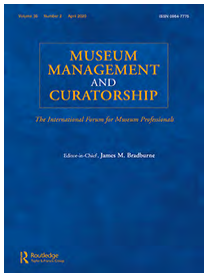

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The implied visitor in a planetarium exhibition

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The implied visitor in a planetarium exhibition

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ABSTRACT

Planetariums disseminate astrophysics, space technology and planetary science to the public. These subject areas are often perceived as being 'hard science' and thus symbolically associated with the masculine. To what extent is this gendering also present within planetarium exhibitions? We address this question with a three-fold conceptual framework combining theories on the implied visitor, gender, and science exhibitions, respectively. We analyse to what extent gendered structures are embodied within the exhibition *Space Mission*. We find that the dominant discourse within the exhibition is one that presents science as technical, fact-based, and individualist, organised through competitive and game-like activities. We argue that these characteristics are associated with masculinity, thereby reproducing the discourse of astrophysics as being within the masculine domain and potentially excluding a large diversity of visitors. We offer some hypotheses about the origin of this gendering and discuss its implications.

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Introduction

The *raison d'être* of out-of-school science institutions such as museums, science centres, and planetariums is to disseminate and communicate science to the general public in ways that are distinct from those used in school science settings. Dramatic, interactive, and immersive experiences are often used to stage encounters with science in out-of-school environments, with the objective of motivating and inspiring visitors from a range of backgrounds. However, research is making it increasingly clear that what to some visitors is a welcoming and engaging environment may to others be a place of exclusion and non-belonging. In many cases, exhibitions and other science education activities in out-of-school institutions seem to be structured in ways that reflect implicit assumptions about what constitutes a standard visitor, effectively excluding those who do not fall into that category (Dawson 2014). In the present study, we develop the notion of this assumed or implied visitor (cf. Achiam and Holmegaard 2015) as a way to interrogate science education environments.

Our study is focused on planetarium exhibitions for two main reasons: First, even though they are growing in numbers and popularity, the educational potential of planetariums is relatively under-researched (Slater and Tatge 2017). Given that collectively,

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out-of-school science experiences are thought to increase interest in science as well as recruitment to science study programmes (Alexander, Johnson, and Kelley 2012; Dabney et al. 2011), understanding the specific educational contributions of planetariums is a worthwhile task in its own right. Second, and of key importance here, planetariums disseminate and communicate astrophysics, planetary science, and space technology. These are considered to be some of the more abstract and 'hard' sub disciplines of the natural sciences, and thus potentially gendered towards the masculine end of the gender spectrum (Leslie et al. 2015). We are interested in whether this potential gendering is present in the astrophysics, planetary science, and space technology disseminated by planetariums, and to what extent it co-determines the identity of the implied visitor.

Conceptual framework

Epistemologically, this study is located at the intersection between what Anderson and Ellenbogen (2012) designate as the relativist–contextualist and the critical theorist perspectives, respectively. Following the relativist–contextualist perspective, we acknowledge that ultimately, the exhibition experience consists of the visitors' construction of their own meanings and understandings, based on their predispositions as well as their interactions with the exhibition. However, following the critical theorist perspective, we focus on how the organisation of the exhibition can act to empower or disempower those visitors (cf. Treagust, Won, and Duit 2014). Accordingly, we examine the organisation of knowledge and artefacts in an exhibition (Meng 2004) to identify the dominant discourses imparted by that organisation and thereby, the implied visitor.

In the following, we develop three conceptual areas of focus, namely the implied visitor, gender, and science exhibitions. We synthesise these three areas into a coherent framework to investigate the gender identity of the implied visitor in science exhibitions. We then present the object of our study, the exhibition *Space Mission*, and proceed with our analysis.

The implied visitor

The concept of the implied visitor is inspired by Ulriksen's (2009) *implied student*, which is in turn inspired by the *implied reader* developed by Wolfgang Iser. Ulriksen (2009) defines the implied student as:

> *[T]he study practice, the attitudes, interpretations and behaviour of the student, that is presupposed by the way the study is organised, the mode of teaching and assessment, by the teachers and in the relations between the students, enabling the students to actualise the study in a meaningful way.* It is presupposed that students can act in and with this structure, and it provides the students with specific possibilities for acting in the study (p. 522, italics in original)

Just as Iser (1984) describes the implied reader as the result of the mutual co-determination of a text and its reader, Ulriksen describes the implied student in terms of the 'conditions for interacting with the educational form and content offered by the study' and the resulting ways in which the student 'does' their study (Ulriksen 2009, 522).

In the same way, we think of the implied visitor as being shaped by the characteristics of the exhibition environment they encounter and the way these characteristics prompt them to bring their personal predispositions to bear on that encounter. In our case, the

external characteristics include, among other things, the way an exhibition is designed, the modes of interaction it offers, and the more overarching culture of the institution as it is expressed in terms of what it means to be a visitor. As discussed, these external characteristics regulate how visitors can mobilise their prior knowledge and experiences to interact with the environment in ways that are considered legitimate. In summary, we use the notion of the implied visitor as a lens to understand the conditions for reception and interaction with the content and form presented within a science exhibition.

Gender

In the present study, the term *gender* is used in accordance with the definition of the European Commission to refer to the culturally enacted identity of a person. It does not equal biological sex, nor is it an innate characteristic of an individual. Rather, gender is changeable over time and has wide variations both in and between cultures (European Commission 1998). An individual's gender identity is thus constantly being negotiated and legitimised in interactions with other individuals, with institutions, communities, and cultures (Risman and Davis 2013), although the biological sex of the individual in question constrains the range of gender performances that are considered authentic or legitimate. This means that gender is often performed in terms of a 'heterosexual matrix' where femininity and masculinity are oppositionally and hierarchically defined (Butler 1990). In other words, performing gender means acting in a way that is recognised as intelligible and legitimate in a particular place (e.g., a planetarium) in a specific situation (e.g., interacting with an exhibit) (Silfver 2018).

What are intelligible and legitimate ways of acting in accordance with this heterosexual matrix? Francis (2000) studied the formation and enactment of gender within contemporary British classrooms from a social constructionist and feminist perspective. Based on her observations, she presented a binary system of traits that are predominantly associated with either masculinity or femininity (Table 1). This binary tabulation was since validated in studies of boys' (Archer et al. 2016) and girls' (Dawson et al. 2019) gender performances in science exhibitions in the UK. Similar gendered patterns were observed in a smaller-scale study carried out by Dam, Linderoth, and Drejer (2014) in a Danish primary school setting. In the Danish study, girls were more likely to take on passive roles in science, while boys were more likely to be active and creative risk-takers. Boys were considered to be naturally interested in science, while when girls expressed engagement in science, they were considered to be inappropriate or 'wrong' by their peers (Dam, Linderoth, and Drejer 2014). This pattern was also observed by Silfver (2018) in the interactions between girls, boys and an exhibition during a visit to a Swedish science centre (Table 1).

Table 1. Select traits symbolically associated with either the feminine or the masculine in three Northern European societies.

Feminine	Masculine	Reference
Emotional	Rational	Francis (2000)
Frail	Strong	Francis (2000)
Cooperative	Competitive	Francis (2000)
Dependence	Independence	Francis (2000)
Passive	Active	Dam, Linderoth, and Drejer (2014)
Not scientific	Scientific	Dam, Linderoth, and Drejer (2014)
Passive	Active	Silfver (2018)
Dependent	Independent	Silfver (2018)

The specific patterns within the science education setting, both in and out of school, may be created through socialisation by both teachers (Carlone 2003; Leslie et al. 2015) and parents in (Tenenbaum and Leaper 2003) in how they talk to, with, and about girls and boys in relation to science.

The dichotomous attributes summarised in Table 1 should not be thought of in terms of qualities of a given individual; rather, they denote traits which in Northern European society seem to be associated with femininity or masculinity. Accordingly, they provide a grid with which we can describe the gendered performances prompted by an exhibition setting (cf. Archer et al. 2016). However, we are aware that the act of categorising traits as feminine and masculine is not value-free (Dawson 2018). We must therefore continuously remind ourselves that when we research exclusion by labelling traits in this way, we risk reproducing the stereotypical assumptions we are trying to redeem.

Science exhibitions

Drawing on the two previous sections, we consider the implied (gendered) visitor to be co-constructed by the discourses and practices of science that are represented in an exhibition, and by the conditions for reception and interaction that these representations offer. To operationalise these notions, we parse the science exhibition into its component parts, namely the hierarchy of exhibition, clusters, exhibits, and tasks (Achiam and Marandino 2014). The level of exhibition denotes the overarching topic of the exhibition (e.g., *Space Mission*). This level is often signified by an introductory text that presents the topic and scope and answers the question of what the exhibition is about (Chicone and Kissel 2014). At the next level, *clusters* are groupings of exhibits that subdivide or thematise exhibition content into more manageable quantities. *Exhibits* are the self-contained units that populate the exhibition, and may consist of objects, groupings of objects, or interactives. Finally, exhibits are often comprised of individual *tasks* which, when accomplished together, mediate the exhibit's meaning (Mortensen 2011).

At each of these levels, gendering conditions may be embodied. For instance, Levin (2010) argues that an exhibition's 'language' (i.e., the way its content is organised as a whole) may prompt certain gender-specific patterns of interaction or circulation. The way in which clusters parse exhibition content also has implications for how visitors can interact with that content: Categories based on conventional disciplines may reinforce gendered hierarchies, while experience-based ways of subdividing content are more broadly inclusive (Hein 2010). And finally, Oudshoorn, Saetnan, and Lie (2002) and Berg and Lie (1995) discuss how the modes of interaction offered by objects and their staging may privilege certain gendered behaviours over others. Accordingly, in the present study, we examine the discourses and practices of science that are represented by words and suggested by design and organisation at the levels of exhibition, cluster, exhibit, and tasks.

Method

We now turn to the setting that prompted our original inquiry – the exhibition *Space Mission* in the Planetarium (formerly Tycho Brahe Planetarium), in Copenhagen, Denmark. In the following we describe *Space Mission* and outline our data collection procedure. We then apply our constructed conceptual framework to analyse the collected

data with a view to identifying the implied visitor, and more specifically, to understand to what extent this implied visitor is gendered.

Study setting

Planetarium is the largest planetarium in Denmark. In addition to the ubiquitous planetary dome, the Planetarium has about 1000 m^2 exhibition space. *Space Mission* is located in a 100-m^2 space. It was completed in 2014, and focuses on unmanned space exploration.

The exhibition consists of an entrance area and three thematic clusters entitled *Ground Control*, *Space Missions*, and *Planets and Comets* with collectively ten exhibits. The entrance area displays the title *Space Mission* and a brief introductory text (Figure 1). Each of the three clusters *Ground Control*, *Space Missions*, and *Planets and Comets* has an introductory sign with text and a touch screen (Figure 2). The colour scheme of the exhibition is black with white, yellow, blue, and orange accents.

Data collection

The data analysed in the following was collected in January 2017 by us, the authors, and consists of field notes and photos of the elements of *Space Mission*, including interactive panels, hands-on exhibits, and texts. We first familiarised ourselves with the data by mapping the exhibition's organisation with the concept mapping tool Mindjet Manager

Figure 1. The title and introductory text at the entrance area of *Space Mission*. Translated into English, the text reads 'Space Mission is an exhibition about finding the secrets of the Universe. Space missions are voyages of discovery where comets, planets and galaxies are investigated. In space we can find the answers to questions such as: How was our Universe created? How did life come into being? Are there others out there?'

Figure 2. The introductory sign for the cluster Planets and Comets. The text reads 'The first expeditions studied the Earth and the Moon. Later, space missions concentrated on the other planets in the solar system. And today, technology developed here on Earth has left our solar system and is now travelling through unexplored territory. The Voyager 1 and 2 space probes are carrying information and images from the Earth. One day they may be discovered by intelligent beings far away in outer space'. The illustration shows the relative sizes of the Sun and planets in our solar system, and the touch screen gives access to additional information, a quiz, and a game-like activity in which the visitor can use the gravity of the Earth and Moon to steer a spacecraft to Mars.

(explained in the following section). This allowed us to gain an overview of the different themes and topics presented in *Space Mission*, as well as the levels (exhibition, cluster, exhibit, and task) at which these themes and topics were presented (Figure 3). Subsequently, we were able to characterise the exhibition's content and form at each of these levels.

Concept mapping

Concept mapping was developed as a way to visualise the way content or knowledge is organised. Concept maps typically represent content as a number of concepts, linked to one another with connecting lines that indicate the relationship between the concepts (Novak and Cañas 2008). Although concept maps are most often used to represent the cognitive structures of learners, they have also been used to visualise the content embedded in educational materials or milieus such as museum exhibitions (cf. Mortensen

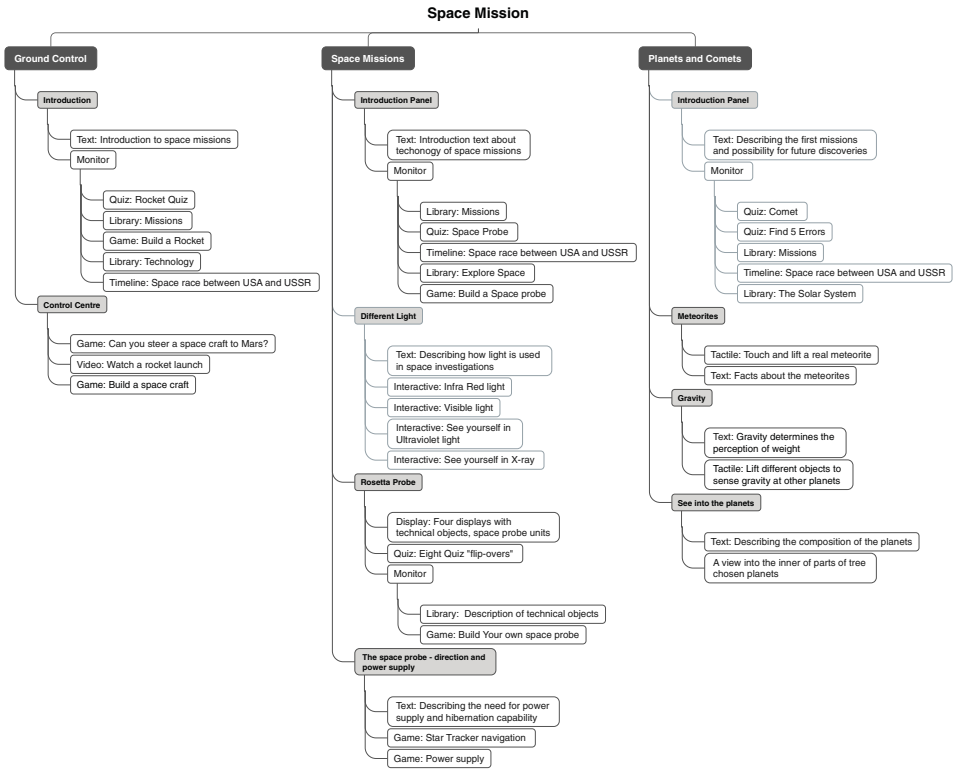

Figure 3. Concept map of the themes and topics presented in the exhibition *Space Mission*, organised into exhibition, cluster (black), exhibit (grey) and task level (white).

2010). Here, we map the organisation of content in *Space Mission*. Because the exhibition is organised into clusters, exhibits, and tasks, the resulting concept map reflects these levels (Figure 3). It illustrates that the exhibition has three clusters, comprised of ten exhibits; these ten exhibits are comprised of about 39 individual tasks.

Space Mission – content, form and organisation

As shown in Figure 1, *Space Mission* greets its visitors with an introductory text that invokes some of the profound questions related to the Universe and our place in it. It asks 'How was our Universe created? How did life come into being? Are there others out there?' and positions space travel as a means to answer some of those questions. In contrast, the exhibition's three clusters divide space and space travel into themes based in part on the disciplinary classification systems of astronomy (*Planets and Comets*), in part on the technical aspects of space travel (*Ground Control* and *Space Missions*). This approach seems to be supported by each cluster's introductory text and touch screen, with its technical and factual information, time lines, and screen-based activities.

The majority of the exhibition's ten exhibits feature mechanical and logistical aspects of space travel ('guide a space probe' or 'build a space craft'), embodied in interactive digital interfaces. Of the 39 tasks contained in the ten exhibits, seven are monitor based games or game-like interactives, six are quizzes based on technical knowledge or objects, six are

data bases with a focus on technical and factual knowledge, and three tasks are timelines with historical, factual and technical content. A smaller number of tasks take alternative approaches. For instance, four tasks are interactive installations where visitors can see themselves in light of different wavelengths, while two are tactile installations that invite visitors to touch meteorites or lift different objects to get a sense of gravity on different planets. One display includes artistic representations of the inner cores of different planets in the solar system.

Thematic analysis

Finally, we carried out a qualitative thematic analysis (Braun and Clarke 2006) of *Space Mission*. In this analysis, we used the binary tabulation presented in Table 1 as a top-down lens to understand how symbolically feminine and symbolically masculine traits play out in different ways across the exhibition's content, form and organisation (made visible to us by our concept map). At each level of the exhibition, we analysed objects, texts and interactives. Texts were thematically analysed based on their topic and word use, and objects and interactives on what kind of activity they offer. These themes, together with their connection to the gender theoretical perspective will be presented in the following sections.

Results

The thematic analysis of *Space Mission*'s content, form and organisation gave rise to four dichotomies that manifest symbolically feminine and symbolically masculine traits in different ways: (1) individual versus multiple visitors, (2) competitive versus collaborative, (3) technical versus humanistic, and (4) facts versus 'big picture'. In the following, we discuss how these themes cut across the exhibition, and how collectively, they co-construct the implied visitor. We present selected aspects of the exhibition to exemplify these themes and illustrate how we abstract the implied visitor from them.

Individual versus multiple visitors

For a large part, *Space Mission* addresses individual visitors. Although there are several examples of texts and designs that focus on, or invoke, social groups of visitors, the majority of the exhibition seems to consider single visitors as the target audience. We found a focus on groups of visitors in the exhibition's introductory text (Figure 1) which asks profound questions that concern all of humanity ('How was our Universe created? How did life come into being? Are there others out there?'), thereby potentially engaging visitors in shared reflections about the possible answers and their implications. Our shared humanity is invoked in other places in the exhibition as well, for instance in the text for the cluster *Space Missions*, which reads:

> In 1957 Sputnik 1 was the first space probe to successfully orbit the Earth. Since that time, men have walked on the Moon, and we have sent space probes beyond the boundaries of our own solar system.

Some exhibits, as well, offer opportunities for shared experiences, for instance *Meteorites*, where the space allows visitors to potentially cluster around the fragments and lift them together.

In contrast to these examples, *Space Mission* includes numerous texts describing exhibits and tasks that use the pronoun 'du', which is Danish for the singular 'you'. An example is offered by the star navigation task in the *Space Probes* exhibit, which reads 'Your space probe must locate Neptune, and you do this by navigating after the star Regulus in the star constellation The Lion'. The exhibit *Control Centre* in the *Ground Control* cluster offers another example of the focus on the individual rather than groups. Here, single chairs are positioned in front of each *Control Centre* monitor, implying individual rather than shared tasks. In summary, although there are some efforts to invoke groups of visitors and shared experiences, especially at the level of the exhibition and clusters, individual visitors seem to be the focus of the majority of exhibits and tasks.

We consider the first theme, individual versus multiple visitors, to be a variation of the dichotomy between the independence and dependence differentially prompted by science learning situations, as described by Francis (2000) and Silfver (2018).

Competitive versus collaborative tasks

Space Mission includes an abundance of game-like exhibits and tasks that are pervaded by a strong competitive aspect. An example of a quiz with answers that are strictly either right or wrong is offered by a task in the *Rosetta Probe* exhibit, which poses questions such as 'What was Pluto classified as in 2006?' and 'How many times the mass of the Earth is Jupiter?' An example of a competitive task is offered in the *Control Centre* exhibit in the *Ground Control* cluster. This task requires the visitor to first choose the correct spacecraft and then match it with the correct items in order to succeed. This right/wrong distinction suggests a game-like setup that implies competitive, rather than teamwork-centred participation. Additional game-like tasks are found in the *Space Probes* exhibit. Here, in one task (*Star Tracker navigation*) the visitor must control a space probe in a way that is similar to many computer games. In summary, the exhibition seems to emphasise competition over collaboration among its visitors.

We consider this second theme is closely related to the dichotomy between competitive and collaborative traits symbolically associated with boys and girls, respectively (Francis 2000).

Technical versus humanistic focus

Another consistently recurring characteristic of *Space Mission* is its emphasis on the technical aspects of space travel and space technology. We found the technical focus to pervade many of the texts, the displayed objects and the interactive tasks. One example is offered by the recurring task of building spacecraft. In the various versions of this task, the focus is on the technical choices involved in building a spacecraft (e.g., which equipment to choose, which fuel to use) and does not include consideration of the human-centred aspects. Such human-centred aspects could involve the teamwork among scientists from various disciplines, or the more overarching reasons for sending spacecraft into space. Further, the cluster *Space Missions*, which is a large part of the exhibition, has a focus on technical instruments and how to use them. The exhibit *Different Light* in the cluster *Space Missions* offers a final example. In *Different Light*, one task invites the visitor to 'see yourself in a different light', and presents live animations of

the visitor in infrared, visible, ultraviolet and x-ray light. This exhibit arguably takes a more human-centred approach to space technology, yet in explanations of the uses of the different forms of light, it reverts to more technical aspects, for instance:

> On Earth, we use X-rays to look inside the body. When taking an x-ray picture of the body, the radiation is absorbed differently depending on whether it passes through muscles, bones or teeth. Bones have the lightest colour on the image, because they absorb the x-ray radiation the best.

As mentioned previously, the technical approach that seems to run through the texts, objects and interactives contrasts with the introductory text to the exhibition, which introduces space exploration as a means to answer more profound, human-centred questions. In summary, *Space Mission* seems to emphasise the technical aspects of space and space travel, to the relative exclusion of the humanistic aspects.

This third theme, technical versus humanistic, does not immediately correspond to the binary tabulation presented in Table 1. However, Faulkner (2000) elaborates how the distinction between being technology-focussed, on the one hand, and people-focussed, on the other, maps readily onto the sociological distinction between masculine instrumentalism and feminine expressiveness. Accordingly, we consider the technical versus humanistic dichotomy found in the data to be an embodiment of the rational/scientific traits symbolically associated with the masculine versus the emotional/non-scientific traits symbolically associated with the feminine (Table 1).

Facts versus 'big picture'

Finally, we found the exhibition to focus on facts, rather than for example open questions or an attention to the bigger picture. For instance, in the exhibit *Meteorites*, the information connected to the displayed fragment of the Canyon-Diablo meteorite consists of facts about where it was found and how heavy it is. We noted, however, that in this particular case, there is an attempt to connect the visitor's aesthetic experience with the dimensions of the meteorite, as it is mounted on a pole that allows visitors to touch and lift it.

Another example is the database available on all the exhibition's digital interfaces, where visitors are able to seek more information. The information found here is largely fact-based, for instance regarding the Hubble telescope's size and technical capabilities, rather than the kinds of scientific questions it might answer. The text within these databases is furthermore quite complex, demanding a considerable level of prior knowledge.

The focus on factual knowledge and the visitor's ability to recall it is also present in the aforementioned quizzes that pervade the exhibition. These quizzes demand significant prior knowledge about physics in general, and space technology and astronomy in particular. An example is offered by a quiz where the visitor is asked to point out five errors on a picture of a Mars Rover. In order to do so, the visitor is required to have specific and detailed knowledge of the Mars Rover – knowledge not easily acquirable or even available within the exhibition. In summary, we find that although *Space Mission* in some cases asks open questions or prompts exploration, the emphasis seems to be on reciting – or requiring visitors to recite – fact-based knowledge.

Finally, like the third theme, the fourth theme of facts versus 'big picture' does not immediately seem to sit comfortably within the dichotomies presented in Table 1.

Again, we draw on Faulkner (2000), who discusses how in science, masculinity, reductionism and detachedness are associated with one another, while femininity has stronger symbolic links to holistic and contextual problem solving. On this basis, we consider the theme of facts versus 'big picture' to be shaped by the underlying dichotomy of masculinity as independence versus femininity as dependence (Table 1).

Gender of the implied visitor

On basis of the four themes and their relation to the gender theoretical framework, we now turn to how they may influence the visitor experience. We found that the visitor implied by *Space Mission* and its design and opportunities for interaction is a visitor who is comfortable on their own, who thrives on challenges and competition, and who enjoys and appreciates fact-based and technical knowledge. In other words, the performance prompted by the exhibition is one of independence, active competitiveness, rationality, and attention to technicality. As set out on the Conceptual Framework and outlined in Table 1, these ways of performing are often symbolically connected to masculinity, meaning that boys or men (biological males) are more likely to be able to interact with *Space Mission* in a way that is recognised as legitimate than girls or women (biological females). This means that not only is the visitor implied by *Space Mission* masculine-gendered; the exhibition may actually serve to support the existing masculine-gendered discourse of astrophysics, planetary science and space technology because it constructs those disciplines mainly in terms of masculine opportunities for interaction and meaning making.

Discussion

In the present study, we found compelling evidence that the masculine gendering of astrophysics, planetary science, and space technology that is found in many research contexts where these sub disciplines are realised and enacted, is also present in the dissemination context of the exhibition *Space Mission*, where it co-determines the identity of the implied visitor. Before discussing the implications of this finding, we consider our chosen methodology and what it means for our results.

Methodological considerations

We have carried out a case study to qualitatively analyse the design and organisation of an exhibition. Even though we acknowledge that the results of case studies have limited generalisability, we chose this research design and selected *Space Mission* as our case because we believed it to be a fairly typical or representative planetarium exhibition. We suggest that our study can be understood as an *instrumental* case study (Fraenkel, Wallen, and Hyun 2012), meaning that the findings do not just describe *Space Mission*, but if we pay careful attention to their limitations, we can use them to gain insights about how and why gender is embodied in exhibitions with content from astrophysics, planetary science, and space technology, or even more broadly, from science. In the following sections, we expand on this point.

One question raised by our methodology is related to the choice of an exhibition as the object of analysis. As discussed by Anderson and Ellenbogen (2012), many education

researchers would argue that an exhibition alone cannot predict the experiences of visitors, and therefore, the *interaction* between visitors and exhibitions should be the object of study. Indeed, some readers might question to what extent the (gendered) performances that we claim are implied by *Space Mission* in fact align with realised visitor behaviours. On the other hand, the critical theory perspective that we draw on seeks to examine and problematise the taken-for-granted and sometimes objectivist discourses that are embedded in institutional and cultural contexts (Treagust, Won, and Duit 2014), and that co-determine what constitutes legitimate participation. This line of analytical inquiry seems well-aligned with notions from *critical museology*, which calls for an examination of museums and similar institutions as part of wider cultural contexts (Shelton 2013). It seems the notion of the implied visitor, understood as the assumptions about the visitor that are embedded in the exhibition and/or institution, is neither new nor controversial in this domain (see e.g., Bennett 1995; Knutson 2002; Kreps 2003; Robinson 2017). In the following sections we reflect further on this point.

The dominant discourse of Space Mission

We found the dominant discourse of *Space Mission* to position astrophysics, planetary science and space technology as technical and incontestable domains of knowledge and practice that are distant from social activity. This finding is perhaps not surprising, given the growing body of evidence from research in the formal education system of how science curricula routinely construct a privileged, masculine status for scientific knowledge (eg. Allegrini 2015; Due 2014; Faulkner 2000; Harding 1986; Hughes 2001; Phipps 2007). Extrapolating from these studies and others, we suggest that the visitor implied by this dominant discourse is someone whose identity can readily be constructed in congruence with these characteristics; we further suggest that this visitor is likely male.

However, visitors to *Space Mission* are not passively situated in this discourse; they are active agents in constructing their experience. Studies show how learners are able to negotiate various positions within the constraints of dominant discourses (Gonsalves, Rahm, and Carvalho 2013; Hughes 2001); more specifically, they may adopt or transform the gendered 'scripts' embodied in the objects and environments they encounter (Oudshoorn, Saetnan, and Lie 2002). This means that while some (female or male) visitors may reject the identities made available by *Space Mission*, other (female or male) visitors may well be able to negotiate and construct viable and legitimate identities within its dominant discourse. Although we have not observed such negotiations in *Space Mission*, other studies offer compelling examples. For instance, Archer et al. (2016) showed how a hands-on science exhibition offered boys different identity performances, including 'laddishness', 'muscular intellect', and 'translocational masculinity', while Dawson et al. (2019) provided evidence of different available positions for girls in a science museum, including 'good girl' performances, 'cool' performances, performances that draw on a combination of masculinity and ethnicity, and performances organised around being silent. While not all of these performances were congruent with science identities *per se*, they do exemplify different gendered ways of negotiating science in exhibitions. A perhaps more encouraging finding is presented by Silfver (2018) who showed how a visit to a science centre afforded 'ruptures' in the behavioural norms of girls and boys, allowing them to negotiate, approach, and challenge stereotypically gendered

borders. Taken together, these studies provide support for the idea that although the visitor implied by *Space Mission* is masculine-gendered, it may well be possible for girls and boys, women and men to successfully negotiate it.

Where do the dominant discourses come from?

We have two main hypotheses about the origins of the gendering of *Space Mission*. We have already hinted at the first hypothesis, namely that the gendering of the exhibition was 'inherited' from the locus from which its content was derived – the research and technology domain – which itself is gendered. The second hypothesis suggests that the masculine gendering may result from the 'enlightenment' view of the science and society relation that positions science as dispassionate, rational and distant, and that still permeates efforts to engage the public in science. We shall discuss these two hypotheses in turn.

Our first hypothesis takes a point of departure in the strong association between on the one hand, astrophysics, space technology and planetary science, and on the other, masculinity, in the domains of scientific and technological research and practice. Numerous studies have provided evidence of gendering and gender inequity in these domains, most recently in a focus issue of Nature Astronomy, which describes how gender bias in astronomy, astrophysics and planetary science leads to 'very real deficiencies in the representation of women […] in almost every aspect of scientific discourse' (Editorial 2017). This includes, for instance, the participation of women in spacecraft science teams (Rathbun 2017) and the gender bias in citation counts in astronomy publications (Caplar, Tacchella, and Birrer 2017). The claim we make here is thus not that that astrophysics, space technology and planetary science are gendered (they are), but that when content from these domains is selected, deconstructed and reconstructed for exhibition purposes ('transposed', cf. Mortensen 2010), the gendered biases and practices of those domains may be transposed into the exhibition as well, if the exhibition developers are not explicitly aware of them.

There seems to be evidence to support this hypothesis. First, in informal conversations with the head designer of *Space Mission*, it became clear that she took for granted the gendered biases that she herself had experienced during her astrophysics studies. She described herself as tomboy who had 'been able adjust and play by the masculine guidelines set up in the scientific community and within the astrophysics study programme' (T. Ibsen, personal communication, 4 April 2017). In addition to being an interesting example of a masculinised performance of gender by a female astrophysicist, we consider this statement to be anecdotal evidence that at least one of the designers of *Space Mission* was influenced by the gendered culture of astrophysics to the extent that she reproduced this culture within the exhibition design.

Second, there are numerous examples from the literature of gender biases in natural science exhibitions that seem to originate in the gendered practices of the natural sciences. For instance, Machin (2008) discusses the androcentric displays of birds and mammals at the Manchester Museum in terms of the predominantly male community of scientists there, while Levin (2010) presents a compelling exposition of how evolution exhibitions reproduce the white, male norms of 'real' scientists. These more recent texts resonate with Haraway's (1984) influential work on how museum exhibitions reproduce

the gendered hierarchies of the natural sciences. Collectively, these researchers and others support our hypothesis that gendered science can and does give rise to gendered science exhibitions.

The second hypothesis about the origins of the gender bias in *Space Mission* suggests that the masculine gendering may result in part from the 'enlightenment' view of the science and society relation that continues to permeate public engagement efforts (Davies 2014; Elam and Bertilsson 2003). This view positions science as dispassionate, progressive, rational and abstract; at the same time as science is *separate* from the public, it is considered to be unequivocally *good* for that public (Irwin 1999). In fact, the 'enlightenment' perspective is also found at the core of promotional materials and outreach activities of space agencies such as the European Space Agency (ESA) and the US National Aeronautics and Space Administration (NASA). These activities and materials promote the idea of space technology and exploration as sources of universal benefits to humanity, yet do not provide any real public access to those technologies or infrastructures (Griffin 2014).

We thus hypothesise that the exhibition *Space Mission* was realised in an institutional and cultural setting governed by the 'enlightenment' point of view (cf. Achiam, Nicolaisen, and Ibsen 2019). Because this viewpoint does not critically question science or its practices, the conditions were present for the development of an exhibition that presents astrophysics, space technology and planetary science as unproblematically factual, technical and rational, rather than presenting it in terms of its more humanistic aspects.

Conclusion

On the basis of the discussions offered in the previous sections, we argue that the masculine gendering of the visitor implied by *Space Mission* may hinder the inclusion of visitors across the gender spectrum. Even though we have suggested there may be ways for visitors to negotiate the dominant discourse, the subtle and not-so-subtle insinuations of astrophysics, space technology and planetary science as masculine endeavours may precipitate within them, potentially reinforcing the sense of *Space Mission* as 'not designed for us' (Dawson 2014). If the aim of our shared science education institutions such as the Planetarium is to disseminate science to the general public, by definition this dissemination should be equally accessible to all. We thus add our voices to the call for more research on how to provide more equitable experiences with science outside the classroom' (Dawson 2014; Scantlebury 2014; Silfver 2018).

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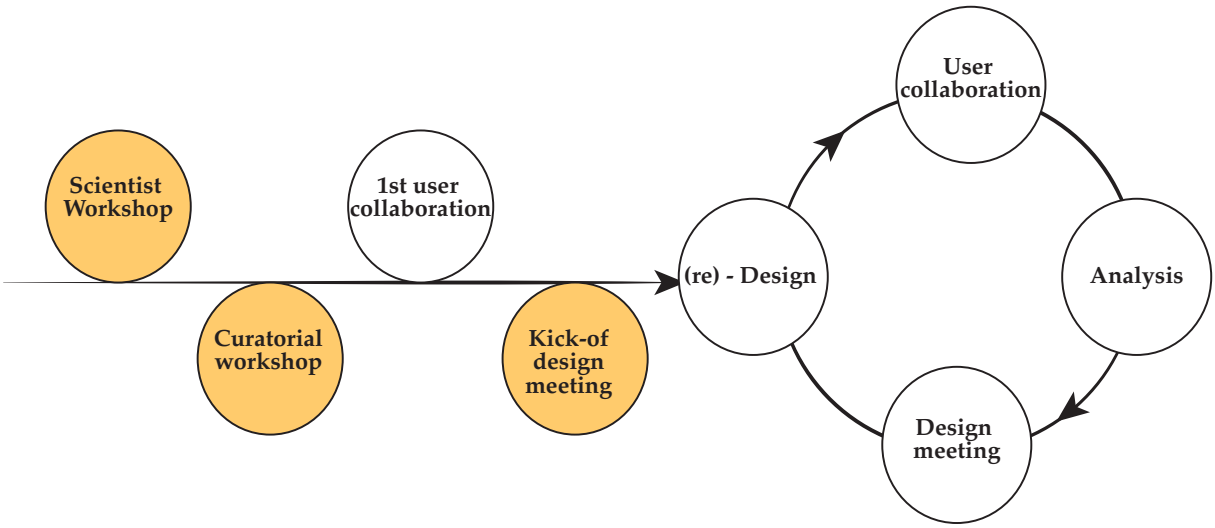

Figure 14: Figure illustrating the steps in the design process which is the focus of [P3]. The circles marked with yellow, the scientist workshop, the curatorial worksop and the kick-of design meeting are the three phases in focus in this paper.

4.3. [P3] 'We are part of the Universe, the Universe is part of us': Transforming astrophysics in the Planetarium

This paper is the first paper in the prospective part of the thesis, and it answers the first part of the following research question (in bold):

> **[RQ2] What are the design conjectures of astrophysicists, staff members and design experts working towards the design of an exhibition (especially: what is the gender of the implied visitor in these conjectures),** and how can these conjectures be synthesised with insights from gender research to create exhibit design prototypes?

The focus of this paper are the first steps in the design process (as highlighted in the figure 14), and the actors who were part of this process (the astrophysicist, the planetarium group, and the design group). Specifically, in this paper we look at what are the dominant discourses of ASTPS in the initial deconstruction of the content for the exhibition. We discuss how these discourses are then disrupted through the implementations of postmodern feminist perspectives, and how these replace the existing discourses with more inclusive ones.

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‘We are part of the Universe, the Universe is part of us’: Transforming astrophysics in a planetarium

Line Bruun Nicolaisen, Marianne Achiam & Tina Ibsen

1. Introduction

Knowledge of astronomy has always held power. From ancient times, there has been a divide between those close to the sky, and those far from it; a divide of often-divine connotations (Selin, 2000). This uneven distribution of power has persisted from early astronomy to its modern Western forms (Penprase, 2011; Gorman, 2005). Today, inequitable power structures are formed throughout scientific culture (e.g. Haraway 1988; Harding 1991).

When museums create exhibitions about science, they purposefully deconstruct scientific knowledge, values and practices and reconstruct them to create environments that appeal to their visitors. This de- and reconstruction runs the risk of inadvertently reproducing the biases, dilemmas and inequalities of science (cf. Nicolaisen & Achiam, 2020; Levin 2010). Ultimately, the inequalities reproduced in this way can lead to a misalignment between the institutions and those they are set to serve, which results in social, economic, and ethnic exclusion (cf. Dawson, 2014). This problem has been observed and challenged more recently across a range of museums (e.g. Robinson, 2017; Christensen, 2016).

Uncovering, analysing and critiquing these biases are pursuits in their own right. Here, however, we discuss how to go even further by promoting change. We are aligned with ‘third wave’ museology, which focuses on both exhibition design and practice (McDonald & Basu 2007, MacDonald 2007) when addressing the dilemmas museums are facing (Hein, 2010). We report on the first phase of a study which builds on theory through design (Markussen, 2017) by linking research, design and practice through an iterative design experiment as a means to address gender inequity. Specifically, we discuss how the Planetarium in Denmark underwent a redefinition process, emerging as an example for institutions facing similar dilemmas (cf. Hein 2010).

In general, planetariums differ from museums in that they do not rely on objects from collections to disseminate their scientific and technical subject matter. However, like museums they disseminate scientific subject matter to the general public, and like some science centres and museums, the Planetarium has been challenged by falling visitor numbers in recent years. In response, it launched a strategy in 2016 to re-establish its relevance as an out-of-school science education provider. This included inviting a science education researcher to participate in the development of the new permanent exhibition *Made in Space*. The aim of this collaboration was to create an exhibition design that balanced the requirement of representing authentic astrophysics, space technology and planetary science (ASTPS) with the need to create inclusive experiences.

1.2 State of the Art

The objective of *Made in Space* was to make recent research on ASTPS inclusive, relevant and available for a diverse audience. This task is challenging, given the uneven distribution of power and access to ASTPS (Griffin, 2014). The uneven distribution is manifest, for instance, in the Space Race Model (Gorman, 2005), which presents space discovery as a triumph of technological achievement and the natural human urge to explore. It thereby creates a master narrative of the interests of largely white male American astronauts, space administrators, scientists and politicians as universal human values, and downplays the military, nuclear, nationalist and colonial aspirations of space faring nations (Bryld & Lykke, 2000). This master narrative leaves little room for other perspectives, effectively 'devaluing previous, non-technological or other connections to space' (Griffin, 2014, p. 39).

Evidence of these other perspectives is scarce, as they are found in different contexts and manifest themselves in different ways. Recent studies point out how the voices of women are systematically excluded from astronomy (Caplar et al. 2017), how the views of Indigenous people in Hawai'i on astronomy are ignored (Ciotti, 2010), and how Indigenous people in Australia must compete with the needs of a rocket range for water (Gorman, 2017). We argue that these transgressions result from a broader 'culture of positivism' that positions an existing body of knowledge as neutral and scientific rather than a tool to serve certain groups (Kincheloe & Tobin, 2009). This culture leads to exclusionary practises within both research and research communication. We thus urge the community of ASTPS researchers and practitioners to act (cf. Johnston, 2019); we ourselves take action by asking: How can the inequalities of ASTPS be purposefully replaced with more equitable and inclusive framings of knowledge in the development of an exhibition?

2. Theoretical framework

Our research acknowledges that people's ideas, values, and knowledge are shaped by social, political, cultural, economic, gender and ethnic experiences. Science is not exempt from those influences. As discussed, we are interested in how the inequalities inherent in interactions with ASTPS may epistemologically empower or disempower certain groups or individuals. Consequently, we locate this research in the critical theory research paradigm (Treagust, Won, & Duit, 2014), which just like critical museology (Shelton, 2013) stems from the Frankfurt School (Kincheloe & McLaren, 2005). Both have a focus on practice; however, as their domains differ, they tackle different dilemmas and problems in their efforts to challenge and transform institutions for the betterment of the people involved (Treagust, Won, & Duit, 2014).

We see institutions as being defined by the rules, conventions, and indeed power dynamics that constrain and enable people's behaviour and thereby structure social interactions. These rules and conventions may be explicit and accepted as official, or they may be implicit, created and enforced outside officially sanctioned channels (Waylen, 2014). Institutions, in turn, are embedded in broader societal and cultural contexts with their own sets of rules and conventions that interact with those of the institutions. This view of institutions as being embedded in societies, and knowledge being

embedded in institutions, is reflected in our choice of the anthropological theory of didactics (ATD) as the framing for this study (Bosch & Gascón, 2014). The theoretical backdrop of ATD is inspired by the French sociologists Marcel Mauss and Michel Verret; in addition to emphasising the nested nature of knowledge, the theory acknowledges the fundamental human nature of all scientific knowledge (Chevallard & Bosch, 2014). Thus, knowledge is always shaped by the (societal, institutional, disciplinary) ecology that it 'lives' within; when knowledge is transplanted to a new context, it is necessarily reshaped to that particular ecology.

Accordingly, we conceptualise the development of *Made in Space* as the *selection* of ASTPS-related knowledge, values and practices, produced within and adapted to research institutions, and the subsequent *deconstruction* and *reconstruction* of the selected ASTPS-related knowledge, values and practices with the purpose of making them viable in a cultural institution, namely a planetarium (cf. Mortensen, 2010). This study thus tracks the changes in the ASTPS-related knowledge, values and practices through their gradual transformation from research context to dissemination context. Of particular importance are the ways in which the inequalities of ASTPS are purposefully replaced with more equitable and inclusive framings of knowledge. In the following, we describe the inequalities of ASTPS in terms of dominant discourses, which we see as elements of the 'culture of positivism' of the ASTPS research disciplines.

2.1 Dominant discourses in ASTPS

ASTPS as masculine-gendered. A growing body of research provides evidence of the masculine gendering of astrophysics and related sciences. From the inception of space exploration, masculine adventure has been a constant referent (Redfield, 2002), most recently embodied by the postponement of the world's first all-female spacewalk due to the unavailability of space suits in fitting sizes (Connley, 2019). However, this gender inequality is also present in more academic aspects of ASTPS, e.g. citation counts in astronomy publications (Caplar et al., 2017) or workplace experiences (Clancy et al., 2017).

Space research for the good of mankind. Griffin (2014) describes how space industry is often discussed in terms of providing humanity with universal benefits, e.g. ensuring a skilled workforce for the future or educating the global public about the importance of space. Often, Griffin writes, these discussions seem to lack an awareness of people who are not part of the logic of space technology (e.g. by being employed or otherwise occupied by it). Related to the notion of benefit to mankind is the perception of ASTPS research as a selfless response to a higher calling (Redfield, 2002), or even 'sacred duty' (Whitten, 1996).

Exploration-colonisation terminology. The link between space travel and colonial history is familiar to most. Research describes how in discussions of space travel, frontier metaphors and nation-building vocabulary habitually invoke Columbus (Pecker, 1987) as well as terms such as conquest, settlement, expansion and even 'colony' in spite of their present-day negative connotations (Redfield, 2002).

Epistemic authority. Hilgartner (1990) describes how an important narrative among scientists is that of scientific knowledge as their exclusive preserve. Public communication, in contrast, involves the creation of simplified representations for the public to grasp. This distinction serves to ensure the primacy or epistemic authority of scientific knowledge over other kinds of knowledge, and has been observed more recently as well (e.g. Davies, 2008; Garvin, 2001). It also seems to exist among astrophysicists; certainly Griffin (2014) provides evidence of how the space industry seems to place the public in an asymmetrical position of ignorance.

In summary, the four dominant discourses in ASTPS are related to masculine gendering, space research as a common good, exploration-colonisation and the epistemic authority of science. These dominant discourses comprise the analytical lens for the present study.

3. Development of *Made in Space*

The exhibition *Made in Space* opened at the Planetarium in February 2018. The focus here is a series of exhibition workshops that took place in 2016-2017, designated as the scientist workshop, the core team workshop, and the design workshop. Analytically, the development had two main phases: the 'what' phase, in which ASTPS knowledge, values and practices were selected to be included in the prospective exhibition, and the 'how' phase, in which the selected content was transformed and restructured for educational purposes (Fig. 1). The main actors involved in the development process are described in Table 1.

The objective for *Made in Space* was to present ASTPS in a way that was 'accessible, engaging and entertaining to a broad diversity of visitors' (Ibsen, Rasmussen, & Kristensen, 2017). The core team was informed by a study of a previous Planetarium exhibition, *Space Mission*, which demonstrated how the masculine gendering of ASTPS found across academic contexts had been reproduced in the opportunities for interaction and meaning making in *Space Mission* (Nicolaisen & Achiam, 2020). Accordingly, the development of *Made in Space* was intended as a means to not just produce a new and more inclusive exhibition, but also contribute to a general model of inclusive exhibition development for the Planetarium.

4. Method

The results presented here are based on audio recordings of the three workshops, field notes taken by the Researcher (the first author), and the documents produced during the workshops and between them. The data were analysed using the six-steps of thematic analysis (Braun and Clarke, 2006), with the dominant discourses (cf. Hughes, 2001) of ASTPS as an analytical lens. We (first and second authors) coded the data independently of each other, and subsequently compared this coding to verify our categorisations. In more than 90% of cases we agreed; in those cases where we initially disagreed,

we reached a common agreement by revisiting our descriptions of the four dominant discourses. This analysis allowed us to observe the presence of the dominant discourses of ASTPS in the data as well as their gradual replacement in the development of the exhibition.

5. Analysis

5.1 The 'what' phase: Selection of ASTPS

The participants in the first phase of *Made in Space* were invited primarily for their position at the cutting edge of astrophysics research in Denmark, and secondarily for their experience with science communication. In the scientist workshop, these professionals were tasked with identifying the most important astrophysics research in Denmark. They were urged to focus on what this research was, not on how to disseminate it. This work resulted in a preliminary list of more than 20 topics. Subsequently, they were asked to prioritise their list to identify the three most important topics, and selected exoplanets, cosmology and black holes.

In their discussions about these topics, the participants in the scientist workshop used a number of different rationales and arguments. Unsurprisingly, one argument was of the status of these topics at the cutting edge of Danish astrophysics research, but the prevalent lines of reasoning for including these topics seemed related to the dominant discourses of ASTPS. For instance, while research on exoplanets is significant in terms of being on the cutting edge of astrophysics, the participants in the scientist workshop referred repeatedly to exploration and colonisation in the discussions, for instance:

> [Exoplanets as a topic] is good, because it is 'modern Columbus', it is the discovery journeys, it is things you can relate to... you can arrive at Proxima B.

This statement explicitly invokes Columbus as well as the notion that humans may someday arrive at Proxima B, the closest known exoplanet to the Earth. It seems to reflect a frontierist ideal in which new territories are perceived as unowned and 'for the taking' (Small, 2017). In another example, Astrophysicist 3 discusses exoplanets, invoking a colonialist rationale as well as the idea that space research is for the good of mankind:

> We do [research] because of the science, there is not necessarily any financial value in it. But I sometimes like to say that we are also doing this because we would like to find a place we can colonise someday.

It is noteworthy that their references to colonisation seem unproblematic to the participants, given the recent attention to decolonising not just museums (e.g. Robinson, 2017) but also university curricula (e.g. Andrews, 2019; Conana, Marshall & Case, 2016).

When Astrophysicist 3 invokes their motivation as scientific, not financial, in the quote shown in the preceding, they hint at the 'for the good of mankind' discourse of ASTPS. We found a number of

references to this discourse in the participants' discussions about cosmology. One instance was observed in participants' ambition to recruit young visitors to an astrophysics study programme or career pathway, as exemplified in the following:

Astrophysicist 4	What do visitors gain from [cosmology]?
Astrophysicist 2	...enlightenment, on different levels, both for adults but especially for children, right? What is it called - when something leads to - recruitment, is that correct?
Astrophysicist 1	...that research is not just for the chosen few. I mean that if they experience that, they might see themselves as someone who could work with this. [The] recruitment thing is also why I'm here

Another variation of the 'for the good of mankind' rationale is the idea of ASTPS research as a selfless response to a higher calling (Redfield, 2002). We observed this rationale numerous times in the scientist workshop, for instance:

> All science is about "what is the meaning of life and why are we here"; that is what drives every scientist (Astrophysicist 4)

At times, the participants in the scientist workshop seemed to adhere to the epistemic authority discourse. In other words, they considered ASTPS in an idealised way, giving authority to those who know and seeing the public as deficient with respect to ASTPS. This position is evident in the following:

Astrophysicist 4	Most people on the street, they have a worldview which is on a level with what they had in the middle ages, right? I mean, they are not at all…
Planetarium staff 1	...yeah, and there are many people who have heard that the universe started with the Big Bang. [...] There are really many people who think that this was in one place in the Universe, and something the size of a pea exploded and then it became the whole Universe [sighs]

Another manifestation of this discourse was observed in participants' discussions of the capability of the general public to understand scientific knowledge production. Specifically, the participants seemed reluctant to entrust the public with aspects of science that could be misconstrued, e.g. the tentativeness of scientific knowledge, as shown in the following:

Communicator:	We also have to include the angle that the Big Bang model is solid

Astrophysicist 1: This is a recommendation that we give the designers, that these models shouldn't be wrapped in too many reservations; that this is the best suggestion from our models. Because, I think the model that is so important to us scientists, or the theory that is completely misunderstood... [the public seems to think that] one theory is as good as another

Communicator: It is because the word theory has two different meanings in research language and in everyday language

Finally, we also observed references to the epistemic authority of scientific knowledge in the participants' discussions of black holes. The reference to the general public as 'mere mortals' in the second quote seems to elevate the astrophysicists to near-divine status, thereby cementing their authority:

> A lot of people are afraid of Black Holes. Maybe it is also a good thing if it is explained that it is a harmless phenomenon (Astrophysicist 1)

> That is the thing that may be difficult for the... the mere mortals, right, the thing that light is still energy, that it is the energy that is influenced and not just.... Because light has no mass, right (Astrophysicist 2)

In addition to these examples, we observed a number of instances in which the workshop participants spoke more generally about the communication of ASTPS. It was interesting to note how a rule of thumb for some participants was to consider the general public in terms of a 'fourteen-year-old boy' (Planetarium staff 2, Astrophysicist 1). Based on our data, it is difficult to say what lies behind this notion, but it could be a manifestation of the masculine gendering of ASTPS observed in the research literature.

In summary, using our analytical lens of dominant discourses, we identified discourses related to 'for the good of mankind', colonisation-exploration, the epistemic authority of scientific knowledge, and (tentatively) masculine gendering, that were part of the rationales for selecting the topics exoplanets, cosmology, and black holes in the scientist workshop. These discourses served to construct an underlying 'othering', forming a 'them' (the public) and 'us' (the experts).

5.2 The 'how' phase: Restructuring ASTPS

The restructuring of ASTPS knowledge in the 'how' phase was shaped by careful negotiations led by the Researcher, of how to question disciplinary framings of knowledge (cf. Nicolaisen & Achiam, 2020). The initial activity was the core team workshop (Fig. 1), which aimed to clarify the content selected in the scientist workshop, and to restructure that content to reflect a core narrative for the exhibition. The product of the core team workshop was an internal document (Ibsen, Rasmussen, & Kristensen, 2017; the 'curatorial brief'), to be handed over to designers with no specialisation in ASTPS.

The core team workshop

The Researcher initiated a central discussion about inclusion in the core team workshop, which focused on shifting the emphasis of the selected content away from the restrictive, textbook-like categorisation of ASTPS observed in parts of the scientist workshop towards a more human-centred framing (cf. Hein 2010). The following exchange exemplifies this discussion:

> Planetarium staff 2: Part of the aim is also how we use cosmology, and how we have reached these understandings. How we can even study the beginning… and then it makes sense to start with us
>
> Planetarium staff 3: If the message is that one should understand one's own place in the universe, right, then it makes sense to start with ourselves
>
> Planetarium staff 1: When it comes to cosmology, then it is the story about us. I think that many [people] miss that point; they think it is something that happens far away. But in the field of cosmology, it is the big questions you work with. Where do we come from? What processes occurred for us to be here today, and what will happen in the future?

This discussion resulted in a restructuring of the topic cosmology. Rather than taking for granted the discipline-based chronological sequence running from the Big Bang to the present day, the participants in the core team workshop decided to take a point of departure in humans, and trace the constituent elements of humans back to their formation in the development of the Universe:

> Imagine that you arrive at the exhibition, and then you stand in front of something, and then it breaks you apart and says that you consist of water, and this, and this, and then it continues: 'where do these things come from?' Then you have hydrogen and helium from the Big Bang, you have the… the small stars and so on (Planetarium staff 1)

Not only did the restructuring of cosmology reflect a marked departure from the primacy of scientific knowledge, it also provided a basis for a central narrative for the exhibition. Through the discussions, the exhibition's guiding question evolved into 'we are part of the Universe, the Universe is part of us' (Planetarium staff 1). As the workshop participants began to unfold this question, the two other selected topics (exoplanets and black holes) were fit into the larger picture:

> But in this way, the three topics merge into one, right? They don't have to be three different parts in the exhibition, do they? (Project leader)

Thus, rather than having three distinct topics (exoplanets, cosmology and black holes), *Made in Space* now had an overarching theme based on notions from cosmology, with black holes and exoplanets as sub themes (Fig. 2). However, even though the restructuring of the content for *Made in Space* represented a deliberate departure from the epistemic authority of scientific knowledge, we still observed instances of adherence to this discourse in the core team workshop. The following example

is an excerpt from a discussion about how the expansion of the Universe, caused by the Big Bang, allows astronomers to effectively look 'back in time':

> I think it is important that we are aware that regular people don't have that way of thinking. It shouldn't be something that we just throw at them. Because we assume that of course people know that the further you look out, the further you look back in time - but people don't know that (Planetarium staff 1)

Even though they echoed the astrophysicists' notions of the primacy of scientific knowledge, the participants in the core team workshop still focused on finding ways to address the perceived knowledge gap between ASTPS experts and the public. The following exchange illustrates an aspiration to empower prospective visitors to evaluate scientific claims for themselves:

Planetarium staff 2: You can hear in the news that now the age of the Universe has changed. And so people think to themselves, 'okay, so [astrophysicists] are just sitting around thinking strange thoughts'…

Planetarium staff 1: …yeah, or 'why have you invented dark matter, I don't like that'. I think it is in the way we have to present it, that we don't make science up. It is based on science, and that is how we present everything in here. If this is to be an exhibition where we also talk about how we get the results, and how we work with these things, then this will be part of it. Then we will talk about the processes and not just the final results - and then [the visitors] will also see that.

The examples we observed of adherence to the primacy or authority of scientific knowledge came from workshop participants with ASTPS backgrounds. Even though these participants were employees of the Planetarium and fully invested in its *raison d'être*, their alliance to ASTPS disciplinary culture may have made it difficult for them to completely forego its dominant discourses (cf. Cole, 2009). Even so, the Researcher's continued attention to inclusion perspectives in the design work led to a replacement of the dominant ASTPS discourses: colonisation, masculinisation of science, or 'for the good of mankind' in the core team workshop. This replacement was perceived as a positive addition rather than a reduction, as suggested by the following reflection by Planetarium Staff 1:

> I think it is a good thing, as well, when we talk about gender - because then we could have more people sharing one experience. Or maybe even having something that two people can interact with. That is some of the things you found as well, [Researcher], that that is more gender inclusive as well.

In summary, the participants in the core team workshop created a central narrative to encompass the three selected ASTPS topics in a coherent way, and restructured those topics towards a human-centred framing likely to appeal to a broader diversity of visitors (cf. Nicolaisen & Achiam, 2020). The dominant discourses observed in the scientist workshop were gradually replaced with more

constructive considerations of the capabilities of prospective visitors, even if some members of the core team still adhered to notions of the epistemic authority of science. The results of the core team workshop were documented in the curatorial brief, which was subsequently handed over to a design firm.

The design workshop

The second activity in the 'how' phase of the development of *Made in Space* was the design workshop (Fig. 1). In this workshop, the design firm presented their proposal for *Made in Space*, based on the curatorial brief, and discussed it with the core team. Prior to the workshop the Researcher had had extensive discussions with the design team about inclusion, and had shared a set of guidelines on key inclusion elements, including connecting scientific content with learners' bodies, the importance of social experience, emphasising cooperation rather than competition, and a strong focus on visual (rather than cognitive) aspects of ASTPS (Achiam & Holmegaard, 2017, Dancstep & Sindorf, 2018, Nicolaisen & Achiam, 2020).

The design workshop marked the transposition of the ASTPS content from its written form in the curatorial brief into a different modality, namely renderings, animations and visualisations. The discussions in the design workshop were prompted by this modality shift as well as considerations of the inclusion guidelines. One prominent theme was of the intended interactions between *Made in Space* and its prospective visitors. In these discussions, we observed how considerations of the sensory and affective aspects of ASTPS partially replaced earlier considerations of its cognitive aspects. For instance, when discussing the design firm's overarching objective for *Made in Space*, Designer 1 focused on creating a sense of awe and excitement among visitors, rather than 'trying to fit too much information in'. Later, as the discussion turned to concrete design ideas related to cosmology, Designer 1 again invoked the affective aspects of ASTPS:

> One possibility is that we build a kind of a show moment that ties everything together. So every thirty minutes, there is one event where everybody goes 'well, this is extraordinary' [...]. So, one of the ideas is that we do the Big Bang, and that there is a single point that explodes out and kind of fills the entire space. Which would be… which would feel amazing in that space.

Another example of the focus on sensory experiences is the Designers' suggestion to use Kinect, an infrared camera system that allows the user to interface with a visualisation on a screen using their body movements, rather than buttons or toggles. Kinect supports multiple physical engagement patterns (Hsu, 2011), thus affording a diversity of ways to interact with the subject matter.

In addition to their attention to affective and sensory aspects of ASTPS, the Designers also incorporated the strong focus on the social aspects of the exhibition visit as prompted by the Researcher. As they were discussing the Big Bang event, Designer 2 added:

> It is also about creating that communal experience. So, previously you've had lots of individual experiences, you can stand, you can do whatever you want in your space, taking your time, but then we have this moment where everyone is as one. We get this, kind of, this 'wow' moment.

Research has acknowledged the social nature of visits to cultural institutions (e.g. Falk & Dierking, 2013). Indeed, one of the issues of the earlier Planetarium exhibition, *Space Mission*, was its focus on individual experiences rather than shared ones (Nicolaisen & Achiam, 2019).

Finally, although the dominant discourses of ASTPS had been more or less completely replaced by more equitable discourses, we still observed an adherence to the primacy of scientific knowledge. The following discussion is prompted by the description of the Big Bang moment mentioned by Designer 1 in the preceding:

> You show the Big Bang as one point exploding, creating the Universe from one point. But that would mean that we have a centre of the Universe, which we don't. […] This is a misconception that every single science centre kind of continues to promote, and every exhibition promotes this, and people misunderstand it. So, I think that that is one of the things that we in this exhibition really need to be careful about, not to reinforce these misconceptions (Planetarium staff 1)

In summary, the discussions in the design workshop were focused on the affective, sensory, and social aspects of the selected ASTPS topics rather than their cognitive aspects. Although it was not always obvious in the moment that this replacement was taking place, in reflective moments, members of the team would discuss how the Researcher's input had helped them change their focus:

> Yeah, I think the fact that we started this process of you talking about it as well has sort of created a different mindset (Designer 3)

At this stage of the exhibition development, the dominant discourses observed in the scientist workshop were almost completely replaced by more equitable and inclusive constructions of ASTPS. One exception to this pattern was the lingering adherence to the epistemic authority of science.

6. Discussion

We have documented how a practical design experiment gradually and purposefully replaced the inequalities built into ASTPS with more equitable and inclusive framings of knowledge. First, we found several dominant discourses to exist in the ASTPS of scientists and planetarium professionals, namely masculine gendering, 'for the good of mankind', colonisation-exploration terminology, and the epistemic authority of scientific knowledge. These discourses were addressed through a design experiment, based on a theoretical foundation (MacDonald 2007, Treagust, Won & Duit 2014, Markussen, 2017) and persistent attention to the inequitable discourses. As a result, the dominant

discourses were replaced by social, affective and sensory framings of ASTPS. This replacement entailed a restructuring of content as well as the transformation of its form.

We acknowledge that prospective visitors to the exhibition are not passively situated in the scientific discourses they encounter, but are active agents of their own experiences (Hughes, 2001, Nicolaisen & Achiam, 2020). This means that they bring their own perceptions and understandings to bear on *Made in Space*, including, potentially, perceptions of space exploration as a masculine, colonialist endeavour. However, we would argue the changes effected in the design of *Made in Space* allow for alternative receptions, perceptions and interaction with ASTPS content, thereby shifting the *implied* ways of engaging with ASTPS in a more equitable direction (Nicolaisen & Achiam, 2020).

In this study, the 'culture of positivism' that positions ASTPS as neutral and scientific (cf. Kincheloe & Tobin, 2009) was arguably replaced with a 'culture of relativism' in which scientific culture is not necessarily superior to the experiences and perceptions of visitors (cf. Campion, 2017). Thus, the design process can be understood as an experiment in Latour's sense of the word; 'transformative for the people and materials involved' (Latour, 1999, MacDonald & Basu, 2007), set in a broader ecology of societal, institutional, and disciplinary conditions. We turn now to these broader ecological contexts.

6.1 Societal ecology

Astrophysics, space technology and planetary science are part of our shared societal and cultural ecology. ASTPS do not just belong to the élite minority of people directly engaged with them, but have broad significance and relevance (Gorman, 2005). For instance, it has been suggested that the most significant effect of the space programme was not its scientific or technological achievements, but ultimately, its impact on the imagination of the public (Mazlish, 1965, quoted in Geppert, 2018). As policy-makers and critical actors turn towards ensuring inclusive and equitable learning opportunities for all citizens (UN Sustainable Development Goal 4), more attention is being paid to exploring new ways of deconstructing science and re-imagining it to create opportunities that are accessible to all members of society (De Leo-Winkler, 2019; Griffin, 2014, Johnston, 2019). It is within this wider societal ecology the Planetarium is embedded and in which the development of *Made in Space* represents one of an increasing number of efforts to widen public participation in ASTPS.

6.2 Institutional ecology

Of particular relevance to this discussion is the symbolic meta function of science centres, museums, and, we suggest, planetariums. By their symbolic function, we refer to these institutions' ability to suspend time and place to offer the visitors experiences beyond the walls and geographic location of the building (Achiam & Sølberg, 2017). In fact, planetariums are uniquely qualified to create this suspension of time and place, given their long history of dome projection technology that allows visitors to experience 'how it is' in space (Bleeker, 2017; Achiam et al. 2019). In the present study, we saw how this institutional visual regime and imaginary (cf. Shelton, 2013) was used to reconstruct

content from astrophysics, space technology and planetary science to create a proposal for an inclusive and engaging exhibition.

6.3 Disciplinary ecology

Finally, in developing *Made in Space*, the Planetarium joins the ranks of progressive science centres and museums who question authoritative, canonical science and seek instead to engage their visitors in negotiating what science means for them (Sandholdt & Achiam, 2018). This questioning challenges the notion of objectivity, which has historically been an important part of the self-image of the natural science disciplines (Reiss & Sprenger, 2017). However, a consensus is emerging that just like other processes and products of human culture, the natural sciences are constructed by and within power relations in society, not apart from them (e.g. Haraway, 1988; Harding 1991). As a consequence, the natural sciences cannot produce culture-free knowledge (Brickhouse, 2001).

7. Conclusion

In this text, we have shown how a proposal for an engaging and inclusive exhibition resulted from the deconstruction and reconstruction of inaccessible and exclusive disciplinary content. We have documented how the dominant discourses of ASTPS in the initial deconstruction of the content resulted in a divide between the experts and the public, and how these discourses were disrupted through transformative experiments, which replaced the existing discourse with more inclusive ones. This deconstruction and reconstruction was explicitly guided by a *critical* perspective on the culture of positivism associated with the natural science disciplines (here in the form of dominant discourses of ASTPS), but as we have discussed, the particular ecology of discipline, institution and society in which the development of *Made in Space* was embedded played an important *constructive* role. In particular, ongoing societal discussions of inclusion, institutional considerations of planetarium modalities, and the scientific disciplines' gradual coming to terms with the illusion of their objectivity created an ecological context that was conducive to the development of an engaging and inclusive proposal for an exhibition. We suggest that the development of *Made in Space* can be understood as a practice-based illustration of how its developers were able to constructively reconcile a number of different discourses with their actual practices.

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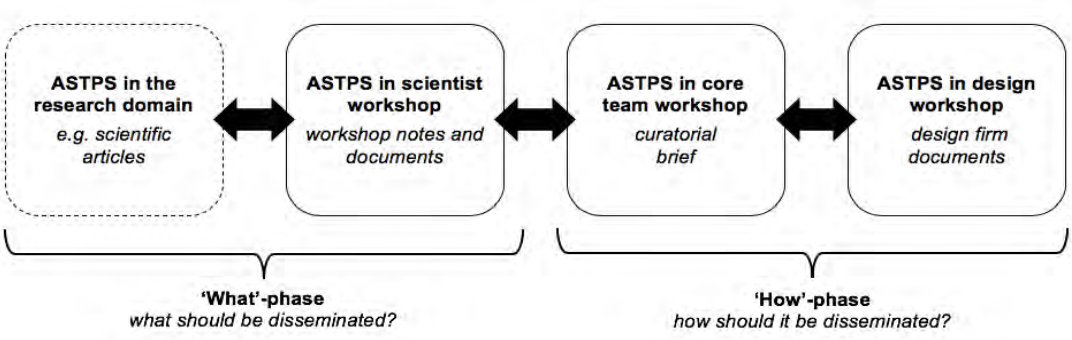

Figure 1. The development of *Made in Space* took place in a series of workshops and was recorded in a number of documents (shown in italics). Analytically, the development of the exhibition can be divided into a 'what'-phase and a 'how'-phase. Figure adapted from Sandholdt and Achiam (2018).

Table 1. The main actors involved in the development of *Made in Space*. The astrophysicists are all members of faculty at Danish universities, while the communicator and planetarium staff members have graduate degrees in astrophysics and work professionally with science communication. The Researcher is a Ph.D. fellow in science education, and the designers are employed at a professional exhibition design firm.

Actor	**Scientist workshop**	**Core team workshop**	**Design workshop**
Astrophysicist 1	x		
Astrophysicist 2	x		
Astrophysicist 3	x		
Astrophysicist 4	x		
Astrophysicist 5	x		
Communicator	x		
Project leader	x	x	x
Planetarium staff 1	x	x	x
Planetarium staff 2	x	x	
Planetarium staff 3		x	x
Researcher	x	x	x
Designer 1			x
Designer 2			x
Designer 3			x

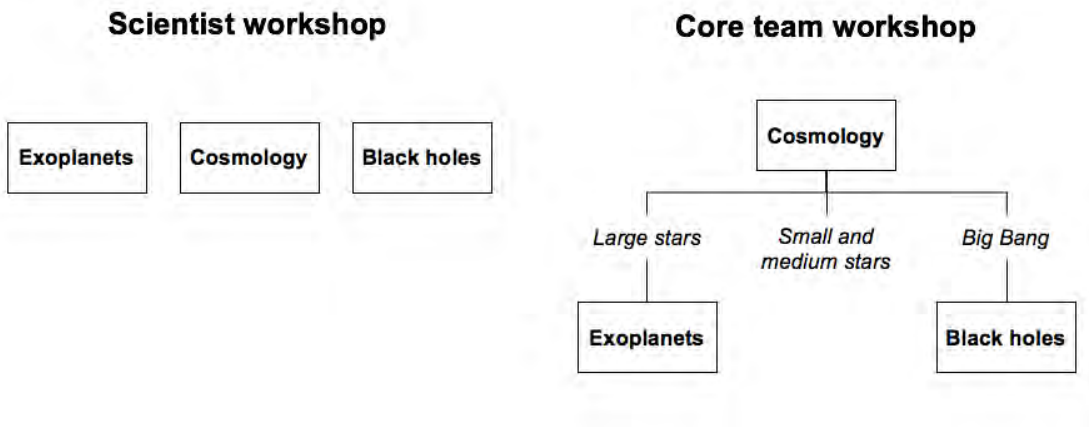

Figure 2. The restructuring of the content for *Made in Space* from the scientist workshop (left) to the core team workshop (right).

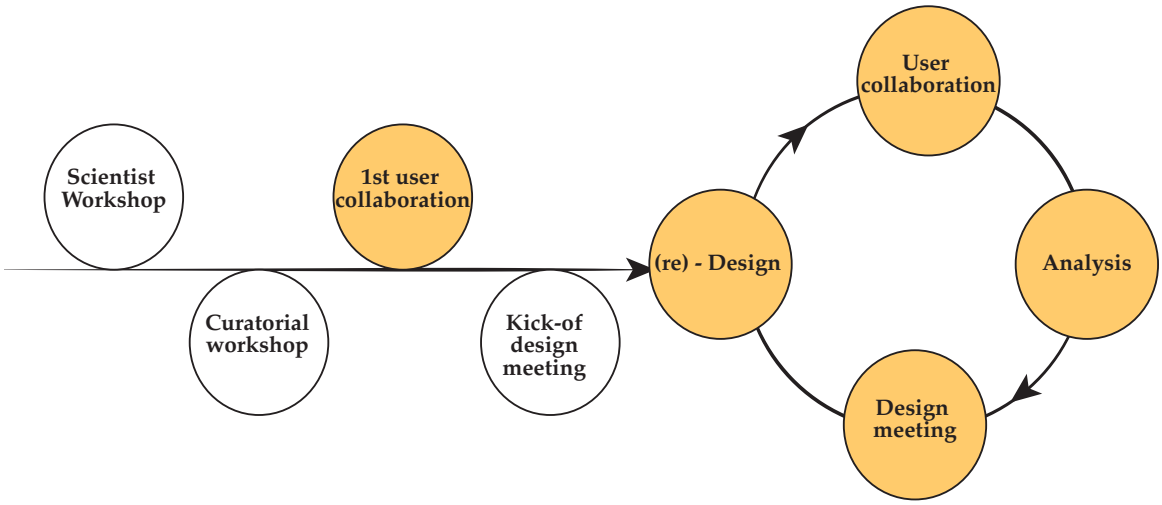

Figure 15: Figure illustrating the steps in the design process which are the focus of [P4].

4.4. [P4] Made in Space: Operationalising postmodern feminism in exhibition design

This manuscript is the second paper within the prospective part of the thesis (see figure 15), and it answers the second part of the following research question (in bold):

> **[RQ2]** What are the design conjectures of astrophysicists, staff members and design experts working towards the design of an exhibition (especially: what is the gender of the implied visitor in these conjectures), and **how can these conjectures be synthesised with insights from gender research to create exhibit design prototypes?**

In this manuscript, I explain the steps in the process of *operationalising* ideas in postmodern feminist theory in exhibition design, through the iterative process of design-based research. The first steps resulted in the formulations of the preliminary design conjectures, which are shaped by both theoretical and more practical perspectives based on existing literature. The second step described in this article focuses on how the users then inform, test, and further develop the design conjectures, until they are embodied in the final design of the exhibition. This article therefore builds on the previous article and is the prerequisite for chapter 5 [**P5**].

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Nicolaisen, L. (n.d). Made in Space: Operationalising postmodern feminism in exhibition design

Made in Space: operationalising postmodern feminism in exhibition design through design-based research

Line Bruun Nicolaisen

Abstract:

While many have used feminist theory to critique out-of-school science institutions for presenting scientific knowledge in ways which may hinder inclusion of marginalised groups, few have researched how we make the critique action-based and promote change. This study proposes design-based research as a mean to operationalise postmodern feminism in an effort to create more inclusive exhibitions designs. The case addressed in this paper is the Planetarium in Copenhagen, and their new exhibition '*Made in Space'*. This article reports on how the iterative design process and the users collaboration qualified and formulated three selected design conjectures. These are: 1) *Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge* 2) *Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making*, and 3) *providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways*. It discusses what the implications of operationalising postmodern feminism in exhibition design through design-based research are, and how this work can inform future design processes.

1. Introduction

Out-of-school science institutions such as natural history museums, science centres, zoos and planetariums play an important role in our society as gatekeepers of scientific knowledge. These institutions transform their visitors (Coffee, 2008, Soren, 2009), inspire career aspirations (Dabney et al., 2011, Fadigan and Hammrich, 2004) and play important roles in promoting informed and

active citizenship (Newman, McLean & Urquhart, 2005). They thus have an important imperative to be equally accessible to all - however, studies show that this is not the case (Sandell, 1998, Dawson, 2014). Inequality and the inaccessibility of knowledge for underrepresented demographics is an omnipresent problematique that transcends society and the scientific community. As out-of-school science institutions are part of society, and tightly linked with the scientific community (Achiam and Marandino, 2014), they are not exempt from these challenges.

Over the last decades, an increasing research effort have described and critiqued the persistent inequities in out-of-school science (Feinstein, 2017). Hein (2010) examined the institution of the museum with a feminist perspective, and argued how museums in general could benefit from a change in their theoretical lens. Levin (2010) used feminist theory to criticise the white, male-privilege undertones imbedded within the exhibits at Natural History Museum London, and argued how this may lead to exclusion of people outside this narrow category. Dawson (2014) used critical theory to study how science museums risk excluding users based on their cultural background. Further, Archer et al. (2019) and Dawson et al. (2016) used post-structural intersectional feminist approaches to study science centres, observing how they are at risk of reproducing or promoting heteronormative and narrow ways of performing gender.

Hence, in their efforts to uncover and understand these challenges, researchers have used critical theory (Robinson, 2017), feminist theory (Hein, 2010, Levin, 2010) and post-structural, intersectional feminist approaches (Dawson et al., 2019). The utility of these theories lies in challenging the systematically inequitable structures within these institutions, thereby making the problems evident. However, the solutions to these problems are not.

One important challenge is that feminist theory still awaits practical realisation, and has not been consistently operationalised through museums (Hein, 2010). Though feminist theory is useful posing necessary critique, it is not yet action-oriented. Accordingly, the next steps for researchers in

responding to the critique is to explore possible solutions. In this article I present an experiment on how to operationalise ideas from one branch of feminist theory, postmodern feminism, by using a design-based research framework, where theory and practice are inherently intertwined (McDonald & Basu 2007, MacDonald 2007).

I will argue that it is possible to operationalise postmodern feminism in exhibition design by collaborating with potential users through iterative design cycles, and that this can result in a different and more inclusive exhibition design. I make this argument by unfolding key aspects of the development of the astrophysics exhibition 'Made in Space' at the Planetarium in Copenhagen, Denmark. Briefly, this process entailed 1) the operationalisation of preliminary ideas on postmodern feminist design of out-of-school science education, 2) the embodiment of these preliminary assumptions in design conjectures that were acted upon by users, and 3) the incorporation of the resulting ideas in the prototypes, visualisations and re-design by a Design Group, and 4) in the final design of the exhibition. The research question that guides this paper is therefore: *How can postmodern feminism be operationalised in an exhibition design through a design-based research approach, where inputs from users and astrophysicists, staff members and design experts are synthesised in the design of an exhibition on astrophysics?*

Setting the scene

Astrophysics is a field of science that is undergoing scrutiny and change at present. An important issue within the related disciplines of astronomy, astrophysics and space science is the persistent degree of exclusion (Johnston, 2019), present at the university level in academia as well as at the primary, secondary and tertiary levels of education (cf. Due, 2014, Danielsson, 2009, Hasse, 2009, Johnston, 2019, Francis, 2000).This exclusion is also manifested in out-of-school settings, for instance in planetariums, where the masculine gendering found across the academic context may

(inadvertently) be reproduced (Nicolaisen & Achiam, 2020). Recently, however, the issue of inequality has been a focus within the astronomy community (cf. Nature astronomy focus issues 2017, 2019) where attention is being paid to underrepresented groups based on gender (Masters, 2016, Caplar et al. 2017, Primas 2019, Bergstrom, Sadler & Sonnert, 2016), ethnicity (Norman et al., 2012), and cultural background (Ciotti, 2010, Swanner, 2013). The study I present here is part of this shared effort.

2. Methodology

The case of the Planetarium

In February 2018 the Planetarium in Copenhagen, Denmark, opened the astrophysics exhibition 'Made in Space'. The opening of this new exhibition was an important step in rebranding and re-creating the Planetarium, moving it from being a 'glorified cinema' (T. Ibsen, pers. comm. March 14., 2017) with a focus on commercial aspects, to having a stronger focus on its core scientific identity. In June 2018, 'Made in Space' was awarded the European Network of Science Centres and Museums' *Mariano Gago Award* in the 'sustainable success' category for being inclusive and engaging.

'Made in Space' was developed as a part of the national research programme *Our Museum*. In the programme, the Planetarium and the University of Copenhagen partnered to explore how to engage non-users in science communication activities. This collaboration created the link between research and practice that allowed me to participate in, and guide aspects of, the co-creation of 'Made in Space'. Furthermore, the collaboration shaped the focus of 'Made in Space' towards creating an inclusive exhibition design by involving the underserved demographic.

The team developing this new exhibition consisted of two main groups that worked in unison, but had different areas of expertise and responsibilities. These will in this text be referred to at the

'Planetarium Group' and the 'Design Group' (see table 1). The Planetarium Group was based at the Planetarium, and included the head of communication, the project manager, and myself (from now on 'the researcher'). The other group, the 'Design Group' consisted of designers, architects and production team members from the design bureau 59productions, based in London, UK.

Theoretical Framework

As discussed in the preceding, this study emphasises inequality and the power dynamics in human interactions, and more importantly, how to change these. It is thereby conceptualised within the critical theory paradigm (Treagust, Won & Duit, 2014, Anderson & Ellenbogen, 2012, Kincheloe & McLaren, 2011). The study challenges the taken-for-granted practices within science exhibition design, and democratises the process by giving voice to groups or individuals who are not normally heard (, Kincheloe & McLaren, 2011).

It may be useful for the reader to recall that the vehicle for promoting change in this experiment is design based research, whereas the engine for this change is feminist theory. This raises the obvious question: How can critical theory and feminist theory act in unison? Arguably, critical theory and feminist theory share a common objective, but differ in emphasis (Martin, 2003). Where critical theory traditionally emphasises *class*, feminist theory has grown from an emphasis on *gender* and *sex*. Common to the two theoretical approaches is that they both seek to unravel, discover, criticise and change structures and discourses that connect and influence our social life (Martin, 2003, Kincheloe & McLaren, 2011); synergies between the two are therefore arguably possible (Martin, 2003).

Further, to view science through the critical lens of feminist theory is not a new endeavour. Since the 1980's, feminist theorists such as Evelyn Fox Keller, Donna Haraway and Sandra Harding have directed a critical gaze at science, arguing that not only is science socially constructed, it also

constructed as masculine (e.g. Keller, 1982, Harding, 1986, Haraway, 1988). However, as mentioned in the preceding, when it comes to changing the social structures, that is, moving from critique to change, matters become more complex.

The present study is guided by the line of educational researchers (cf. Archer et al., 2016, Dawson et al., 2019, Francis et al., 2017, Godec, 2018, Gonsalves, 2014, Holmegaard and Achiam, 2017), who critique and call for change in both in-school and out-of-school science learning environments. In accordance with these research efforts, the present study is positioned within the poststructuralist/ postmodern feminist theory, understanding that gender is socially constructed, and changeable over time and space. It follows that that gender is not limited to traits based on biological sex, nor is it an inherent and static set of abilities with which we are born. Rather, gender is understood to be performative, constructed and changeable as a response to the situational context in which we experience ourselves (Butler, 1990). Our interactions with other individuals, communities, institutions, and cultures shape our understanding of what are intelligible ways of gender performability (Risman & Davis, 2013).

Positioning my research within postmodern feminist approach means that I acknowledge the differences between all individuals, rather than those based on categorisation by sex (Sinnes, 2006). In this study the focus is therefore not on women and girls as a uniform group where 'one size fits all'. Rather, rather the study attempts to promote institutional change from within; to prompt an increased capacity to cater to those who do not easily identify with the 'hard' sciences. As a consequence, I am not interested in examining *the* female point of view (if one such exists), but in understanding the points of view of a more diverse group of potential visitors.

In the following I describe how the design process served as the link between the theory and practice, and how the theoretical point of references as described above were implemented through the iterative process of design-based research.

Design-based research

Design-based research provides a framework to synthesise theoretical insights described in the preceding into the practical design process. The design-based research involves cyclic process of design, enactment, analysis and redesign (Cobb et al., 2003). In a systematic way, it allows researchers and designers, often times embodied in the same person, to understand how certain design elements within exhibits help to meditate meaning (Cross et al. 2007).

Here, I use the notion of design conjectures from educational design research (Sandoval, 2014). Sandoval (2014) describe a design conjecture to be:

> The ideas a research team has about how embodied elements of the design generate mediating processes can be articulated as design conjectures. (p. 22)

In this case, more specifically, I will use the conjectures to explicate the assumptions on *how to operationalise postmodern feminism in exhibition design.* In other words, they will act as the explicit verbalisation and condensation of the evolving and 'fuzzy' design ideas as they exist in the iterative design cycle. The reason why I do not call these design principles or guidelines is that this paper deals with the process of formulating and reformulating the design conjectures, and not how they are met by the actual users of the Planetarium.

I will distinguish between *preliminary conjectures* and *design conjectures.* The preliminary conjecture is based in theory and prior studies, *before* they were acted upon by the user-, the planetarium- and the Design Group. In the following section the development and formulation of these preliminary connecters are described. These were then tested and qualified by the users through the iterative design process, and reformulated to become design conjectures. These then guided the (re)-design of the exhibitions and were embodied in the final design of the exhibition (See figure 1).

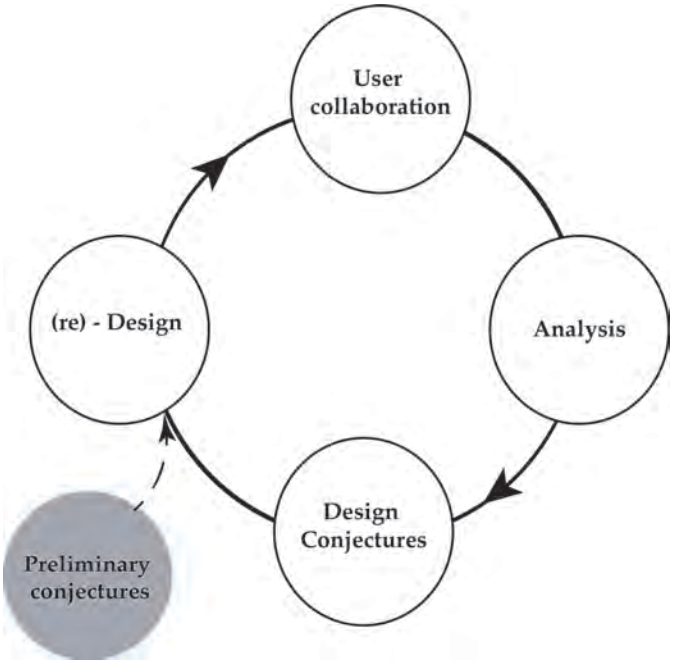

Figure 1: This model shows how the preliminary design conjectures were implemented in the design process, and acted upon by the users through in collaborative user interviews. After the user implementation, their responses were analysed and qualified the design conjectures. These were then embodied in a design output, e.g. a graphic, a prototype, or a text, which then again were presented and discussed with the user group. This iterative cycle continued until the final exhibition opened.

Operationalising postmodern feminist theory in exhibition design

In the following I explain my initial steps in the process of *operationalising* ideas in postmodern feminist theory in exhibition design. These steps resulted in the formulations of the preliminary design conjectures, which are shaped by both theoretical and more practical perspectives based on exiting literature.

The first step was to look at the institution, the Planetarium, and understand the already established 'ways of doing' of the Planetarium's exhibition design practices, with a particular focus on the areas of astronomy and astrophysics. A previous study (Nicolaisen and Achiam, 2020) had analysed the most recent exhibition on space exploration at the Planetarium, 'Space Mission' from 2014. This study was based on critical theory, and observed how the exhibition reflected narrowly defined heteronormative masculine traits (cf. Francis, 2000) in explicitly promoting independence, active competitiveness, rationality and attention to technicality throughout the setup of the exhibition. As an institution, the Planetarium was therefore found to unintentionally reinforce gender stereotypical representations of space science and technology (Nicolaisen and Achiam, 2020). This finding was part of the context in which the process of developing the new exhibition was placed. As a result, the design conjectures developed in the present study were shaped with the intention of renegotiating typical representations of space exploration, astronomy and astrophysics in exhibition designs, thereby allowing for a more diverse approach in engaging with exhibitions.

Second, to begin to understand *what* such a renegotiation could look like, I began by searching for similar projects. However, within the limited literature on planetarium exhibition design, I was not able to find similar studies. I therefore guided my preliminary conjectures on research on how to design inclusive out-of-school learning environments in western settings (Sinnes, 2006, Dancu, 2010, Achiam and Holmegaard 2015, 2017). Design guidelines from this research included, but were not limited to the following: Focusing on the variation in interest and abilities that exists in the users or visitors, rather than separating the visitors into categories based on their biological sex (Sinnes, 2006, Sinnes & Løken, 2014); being aware of the learner's prior knowledge and interest; creating diverse trajectories of inquiry; ensuring that there is attention both on the details and the bigger picture of the subject matter; and ensuring that the designed activity allows for different ways of engaging (Achiam and Holmegaard, 2015, 2017).

However, how can these guidelines be transferred to exhibitions? The fourth step was then to explore how gender inclusion in exhibition design had been studied previously, I included the work of Toni Dancstep (neé Dancu) and the guidelines from the EDGE-project in the initial development of my design conjectures.

	Preliminary design conjectures presented to the designers	
Content design conjectures	Focus on ethical and social aspects, rather than only technical details and facts	Sinnes (2006) Dancu (2010) Achiam and Holmegaard (2015, 2017) Nicolaisen and Achiam (2020)
	Provide context to the content, and pay attention to both the bigger picture and relevant details	Sinnes (2006) Dancu (2010) Achiam and Holmegaard (2015, 2017) Nicolaisen and Achiam (2020)
	Allow for emotional connectedness, rather than detached objectivity	Nicolaisen and Achiam (2020)
	Show the diversity of scientific methods	Sinnes (2006) Achiam and Holmegaard (2015, 2017)
	Allow for open and unanswered questions in science	Sinnes (2006) Achiam and Holmegaard (2015, 2017) Nicolaisen and Achiam (2020)
Physical design conjectures	**Provide social interaction and cooperation, allowing two or more to interact at the same time in a non-competitive setting**	Dancu (2010) Achiam and Holmegaard (2015, 2017) Nicolaisen and Achiam (2020)
	Provide different ways of engaging with content, e.g. think task, tangible objects, use of body	Achiam and Holmegaard (2015, 2017) Nicolaisen and Achiam (2020)

Table 1. In the present study, I focus on the four conjectures that are in bold.

Finally, I generated a list of preliminary conjectures shaped by the studies briefly summarised above. These were presented to the designers and planetarium staff in the first part of the development process, and acted as a starting point for understanding how to design a more inclusive exhibition. The preliminary conjectures are described in Table 1.

It is important to emphasise that the list of design conjectures generated in this way was preliminary, as I wanted the users to have an active role in defining what aspects were relevant for them. In the processes that followed, the preliminary conjectures were thus subject to refinement, qualification, or rejection through interviews with users. For the sake of simplicity, I will focus on three specific design conjectures that were part of the preliminary list of conjectures and eventually embodied in the final exhibition: 1) Creating context, connection and relevance 2) Social and shared experience, and 3) Providing room for open-ended questions and emotional connectedness. These conjectures are bolded in table 1.

Preliminary conjecture: Creating context, connection and relevance

The initial conjecture was to place knowledge of astrophysics in context by paying attention to the 'bigger picture'(Francis, 2000, Sinnes, 2006, Achiam and Holmegaard, 2015, 2017, Nicolaisen and Achiam, 2020), and doing so by connecting the abstract scientific knowledge with our bodies (Dancu, 2010) and our origins. This focus, I conjectured, would allow for a more diverse public to feel motivated and engage with the content of the exhibition.

Preliminary Conjecture: Creating a social and shared experience

A second initial conjecture addressed the physical design of the exhibition and the interactions made possible through this design. It built on the criteria and guidelines from the Hypatia project (Achiam and Holmegaard 2015, 2017) and the work by Sinnes (2006), and addressed general considerations of science learning activities that aimed to create a more gender balanced approach based on ideas from postmodern feminist theory. According to this work, the

design should prompt social interactions and cooperation, allowing for two or more people to interact at the same time in a non-competitive setting (Dancu, 2010, Achiam and Holmegaard, 2015, 2017, Nicolaisen and Achiam, 2020). The tasks should also allow for diverse ways of engaging with the content.

Preliminary conjecture: Providing room for open-ended questions and emotional connectedness

The final preliminary conjecture I discuss here is to allow for open and unanswered questions in science, as well as emotional connectedness (Sinnes, 2006, Achiam and Holmegaard, 2015, 2017, Nicolaisen and Achiam, 2020). Together, these guidelines promote a variety of trajectories into science that are not necessarily bound by technicalities, facts and emotional detachment. The assumption is that in allowing for the unanswered and open-ended questions, it shows astrophysics as non-finite and calls for the use of the imagination (Beford, 2016) which speaks to the non-tangible aspects of astrophysics (Griffin, 2014).

The development processes

I not turn to the actual design process in which these preliminary conjectures where implemented. Figure 2 presents a simplified visualisation of the steps of the design process.

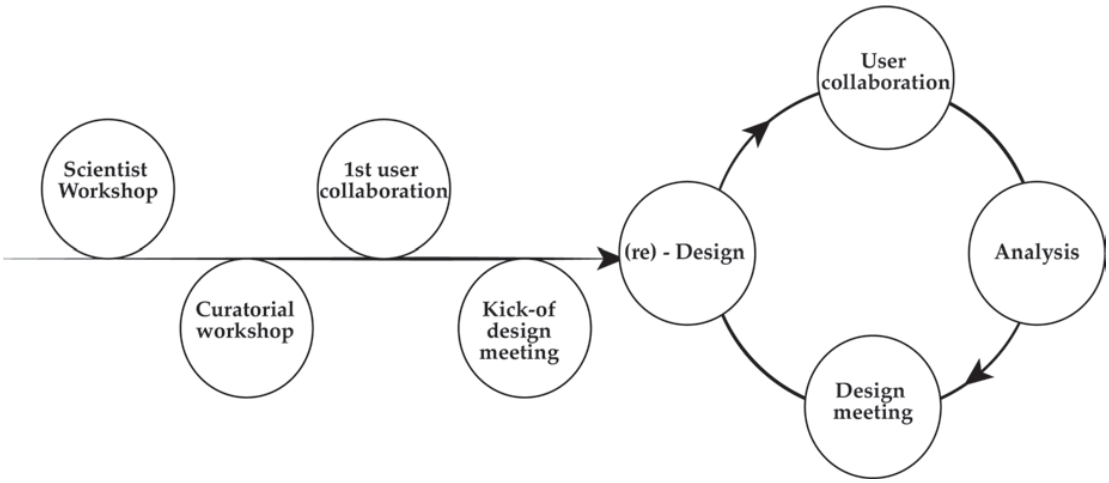

Figure 2: This figure shows a simplified version of the important steps in the design process. The linear arrow indicates the initial workshops in the process, followed by the iterative design cycle.

The first step in the iterative design process was for the Planetarium Group to create a portfolio of cutting-edge astrophysics research, based on input from researchers within the field of astronomy, astrophysics and space exploration.

The second step was to produce a curatorial brief containing an in-depth description of the scientific content, such as a description of dark matter, as well as the key message and frame of the exhibition. The curatorial workshop initiated the development of the brief, and the preliminary conjectures guided the formulation of the brief (For further discussion of this process, see Nicolaisen, Achiam, and Ibsen, in press.). The brief was then adjusted based on inputs from the user group during the first interview. The curatorial brief contained both the key message of the exhibition and a description of the scientific content to be disseminated. It further held information about the gender inclusive approach. The curatorial brief where then presented to the designers at the kick-off design meeting, and preliminary conjectures on how to design with gender inclusion in mind were presented.

In the next step of the process, the designers created schematic designs based on the content of the curatorial brief. Following this phase, the Design Group, Planetarium Group and researcher worked in close cooperation, focusing on design aspects, content, and gender inclusive strategies, respectively. I carried out interviews with the user group during the same period. These interviews clarified the user group members' prior knowledge and interests, museum-visiting habits, and their responses to content, texts and design. The user group members were presented with renderings, animations and visualisations, and I recorded their responses. Subsequently, I presented these inputs to the Planetarium Group and the designers where they were used to guide the development of the design conjectures.

The user groups

The user group in this study were chosen based on three main parameters. First, I was interested in understanding families' use of museums, as families are the target group of the Planetarium. The choice of focusing on 'dyads' consisting of an adult and a child, respectively, was based on my own preliminary observations in the Planetarium as well as on the observation that generally, when families enter museums, they enter together then disperse into smaller groups, often pairs or 'dyads' (Allen, 2002).

The dyads chosen for this study were in the combination's Father/son, Father/daughter, Mother/son and Mother/daughter. The age of the children in the family were between 10 - 13 years. This age interval is based on the target audience defined by Planetarium. The considerations resulting in this age range is that parents were able explain to young children, and that 10 – 13-year olds were able to engage with the content themselves.

However, and perhaps unsurprisingly, recruiting families to participate in an ongoing study, and to be available for non-specified dates for about a year and a half, proved difficult. I was able to recruit four families, with children in the selected age range. The families agreed to at least four interviews of 90-120 min duration.

Finally, I see the users as providing the Design Group with a specific perspective on a particular subject at a specific time (McHardy et al., 2010). In other words, I see my interaction with and understanding of the users as brief snapshots of their whole person. I do not presume that I, through my interviews with them, was able to grasp the full complexity of the users and their relationship with astrophysics.

Materials

During the development of the exhibition, more than 250 hours of conversations and discussions were audio recorded. These recordings include exhibition meetings, workshops, interviews, and design presentations. As part of the data collection, extensive notes and observations were made and linked to each recording. This made it possible to select recordings with particular relevance for the research question, and conversely, to deselect recordings where meetings were concerned with technical and practical issues, such as discussing and planning of meetings with board members, contract lawyers, and carpenters.

Method of analysis

My method of analysis is based on the notion of design conjectures (Sandoval 2004; 2014). I am interested in explicating how the collective design assumptions of the group changed over time, based on the input and influence from theory, the actors involved in the design development, and, most importantly, the users from the user groups. I carried out a thematic analysis (cf. Braun & Clarke, 2006) of the material described in the preceding to trace how the initial design conjectures were shaped, altered and finally embodied in the design of the exhibition.

First, I selected the recordings that were relevant to the research question of the present study, based on my notes. I then re-familiarised myself with the recordings, chose specific passages of interest to the research questions, and transcribed these verbatim. Then, I read through the transcripts with six themes mind that were relevant for the development process and connected to the design conjectures. These six themes relating to the design conjectures were: 1) development of the key message, 2) creating a shared and social experience, 3) attention to open-ended questions 4) tactile experiences, 5) link between scientist and user, 6) immersive experience. From these six themes, I've chosen to present three of them in this text, as they were most significant for the final design of

the exhibition. These three themes were the key message, the creation of the shared experience, and allowing for open-ended questions and emotional connectedness aspects. In the following, I will explain how these three themes evolved from the initial design conjectures and through to the final design.

3. Results

Operationalising postmodern feminism in exhibition design

In the preceding I presented my preliminary conjectures of how to operationalise notions from postmodern feminist theory in the design of the exhibition. In the following, I explicate how these theoretical insights acted upon and were acted upon by the users, the designers, and the Planetarium Group in the iterative cycles in the design process. I continue to focus on the three specific design conjectures selected in the preceding: 1) Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge 2) Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making, and 3) providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways. I present and discuss each design conjecture will be presented in regards to what briefly what the preliminary design conjecture was, how it was influenced by users' input and how it was implemented by the designers and Planetarium Group, and discuss its implications for operationalising postmodern feminism.

Conjecture 1: Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge

The initial conjecture suggests that placing the abstract knowledge of astrophysics in context, and connecting it to users' origins and bodies makes it relevant and relatable. It is implied

by this conjecture that the users find astrophysics abstract, irrelevant and difficult to engage with. This presumption was confirmed in the conversations during the meetings of the astrophysicists and the Planetarium Group, as well as in the interviews with users themselves. For instance, the head of science communication said:

> […] the universe, it is something that is way out there, far away, and why is it important for us? And that's where we need to take this whole history and tell why it is important to people, right? *Head of science communication* (#25, p.2, October 26, 2016)

The users' perspectives on astrophysics are reflected in the following two separate quotes from the first round of interviews, where the interviewees were asked what they associate with astrophysics and astronomy:

> I'm thinking that it is intangible, really - abstract. *Parent F1*
>
> …
> I am amazingly ignorant about it, and every time I read something about it, I just think, God, there is so much to know, and it is so immensely incomprehensible, immensely complicated, and immensely uh …black holes, and… and what was there before the universe came into being? So, it is really abstract. *Parent F3*

The understanding of astrophysics as being 'abstract', 'intangible', and 'incomprehensible' showcases the important and difficult job of making this specific field of science relevant for the users. Therefore, the task of framing the content to appeal to the users, and to deconstruct their prior assumptions of that astrophysics is and how (little) it was related to them was a key focus point in the development process. It was clear that Design Group needed to motivate the users to engage with the exhibition, but more importantly, to make them feel confident and comfortable interacting with unfamiliar scientific knowledge. As a result, the identification and adaptation of the key message, of the exhibition therefore became of high priority. As a consequence, one of the first readjustments of the content and the design were based on the users' feedback, coupled with the preliminary conjecture of creating context, relevance, connection to the content.

How it evolved

In the initial workshop, the content of the curatorial brief was discussed and restructured (cf. Nicolaisen, Achiam & Ibsen, in press.). Briefly, the workshop restructured the content around one key message, rather than maintaining the discipline-related divisions of 'Cosmology', 'Exoplanets' and 'Black Holes' (Nicolaisen, Achiam & Ibsen, in press.). Instead, the content was reshaped to reflect the one key message: 'you are made in space'.

> I'm thinking - and now it is going to be a bit about the method - but can't you imagine that you arrive at the exhibition, and then you stand in front of something and then something will break you into pieces and say that you consist of water, and this and this, and then it when you continue in, where does these things come from. Then you have hydrogen and helium from big bang, you have the … the small stars and so on. And often people see the universe as being something distant and unknown, and 'why should I care?', it is out there, it is far away, it has nothing to do with me. But we want to frame it as our comics history - it is actually our history, going back to before the earth was formed. *Head of science communication*

The assumption that the link between body and universe makes people want to engage with abstract knowledge, was tested during the first round of interviews with the user group. Here, the dyads were presented with a number of pictures, depicting some of the scientific content from the curatorial brief, such as a figure of black hole, pictures of a nebula, and the life cycle of stars. One figure was a picture of a silhouette of a human created by stars, with the title in English 'Human Body Ingredients', and with boxes showing the symbols for important elements, such as 'O' for oxygen. The dyads were then in their individual pairs asked to choose which picture they found the most interesting and intriguing. All the dyads at some point chose the 'Human Body Ingredients' picture among their top three choices, indicating that it captured their interest. Further, when the picture was explained, most found it intriguing and discussed it further. For instance, Parent F3 discusses with their daughter:

> We are blood, meat, tendons, bones, in a way we seem more tangible than the universe. We don't think that we are made up of the same stuff as the universe - that is actually a crazy cool piece of information! And maybe also a good way to make it, what can you say, to bring the universe to us, to make it more relevant. To consider - it is maybe closer than you might think. (Parent F3, #40, p14. April 6, 2017).

The idea of using our bodies and ourselves as a point of focus meant that for parent F3, the universe became 'more relevant' and 'closer', which supported the initial idea of the exhibition key message. For the children, the notion that we are made from elements in the universe sparked their imagination, and one child stated:

> I've heard about it before, but I don't really – I don't really believe it that much, because stars don't just fall down – they don't fall down on us all of the sudden and hit us on the head, and – and then just sprinkles dust all over you, I just don't think so. *Child (m) 1*
> …

This response exemplifies two opposing themes. First, it shows that the notion that we are made in space was complex, and particularly that the use of the word 'dust' could create a misunderstanding of the basic premise of the general key message, as it seemingly invoked ideas of household dust from users' everyday life. Therefore, the word 'dust' and 'stardust' were deliberately kept out of the text and graphics, and the Planetarium Group instead chose to focus on the elements or 'building blocks' of humans.

The second theme was that the idea that we are made of the universe generated a series of imaginary and self-reflective ideas, and sparked interest. Following the above quote, Child m1 holds his arm up, and looking at it, exclaims:

> 'I would see if, if, ahm, if the body actually pulverised, if it would actually be stardust, Child f2

He thereby relates his own body to the key message. This occurred in other interviews as well, as exemplified in the following quote, where another child touches her arm and says:

> … I want to touch my arm to make sure I can feel it. (Child f1)

These users saw themselves as in relation to the content, rather than apart from it. Based on these responses, it was decided that the exhibition would move forward with this narrative as the common thread throughout the exhibition. The 'we are made of the universe' structure and key message of the exhibition therefore guided the curatorial brief, which was subsequently presented and handed over to the external Design Group.

Following this initial stage of the development process, the designers received, read and worked on the design based on the curatorial brief. The next step in the process was the Design Group's first design pitch. The designers took up the initial idea of 'break [the users] into pieces' in the entrance to the exhibition, as first suggested by the Head of Science Communications. In their pitch, the designers suggested a solution of a Kinect (a motion sensing input device) connected to a large screen, which would in real-time show the users' gestures and movements, and a graphic visualisation of the users' own bodies would be presented with the elements that constitute their bodies and where in space these are created. The intended learning outcome was that the body is created from atoms that are made in space. The visualisation of the user's own body on the screen was intended to prompt and strengthen this connection. The first visualisation of the installation was presented to the user groups in the second round of interviews.

In this second round of interviews, all interviewees responded positively to the idea and the first visualisation of the installation. However, based on the first interview and through the course of the second interview it became apparent that in order for the users to engage with this general story of 'the atoms you are made up of come from the universe', the Design Group had to know more about the users' prior knowledge and interest.

While the users found the overall narrative interesting, one important aspect of the narrative, atoms, proved complicated:

> I want to know why I'm reading about atoms- what is it they do to me? What is it that they make work for me - do you understand what I mean?
> Is an atom the same as an element? I don't know! and then I think - I don't understand this - and then I just walk on. *Parent F3* (#60 2 aug. 2017)

> And why did you choose hydrogen and iron? What does the have to do with my body? If you were to say, that it is because you have many hydrogen atoms on the body or - I don't know. Then as a visitor you would think, okay that's we the chose to focus on hydrogen. All the time, keep focusing on how it is related to my body *Parent F3*

Therefore, the idea of 'an entrance' was changed to 'an introduction', creating a new area of the exhibition space to provide the necessary background knowledge on atoms, named *'Introduction'*. This finding shows the importance of both understanding and including the intended user group's prior knowledge in exhibition design. This important feedback would have been overlooked if not for the user group involvement, and at this state the Design Group were at risk of excluding the very group we wanted to include, based on our (wrong) assumptions of what the general public knows. Not introducing these essential topics would have meant that the key message, and general narrative, were at risk of being lost on a large group of users.

Thereafter, the introduction was now carefully redesigned and framed based on the response, input and feedback from the user group. To give one example, this redesign resulted in discarding the initial idea of presenting a periodic table, on which there was a clear response form the users:

> 'I would think 'oh no, I've seen them so many times, those drawing of the periodic table, and it is just - it so complex that it would take me five years to understand it, and I would just skip over it. And then I don't get the things out of the exhibition I could. But what is interesting is the body, that point of departure, and then you should constantly keep the focus on that, on that *that* is why we talk about atoms.' *Parent F3*

This quote explicates the discrepancy between what the Planetarium Group understands to be a good introduction to physics and atoms, and the prior experiences the users have had with these concepts, namely as something they do not understand. Based on these responses, the introduction

instead became focused on just the six elements (H, He, Fe, C, Z and O) and their role in the human body, and presenting tactile objects of each element (e.g. iron, carbon). In this way, the user response guided the final stages of design of the interactive Kinect, the introduction to atoms, and the text and graphics surrounding it (figure 3 and 4 below).

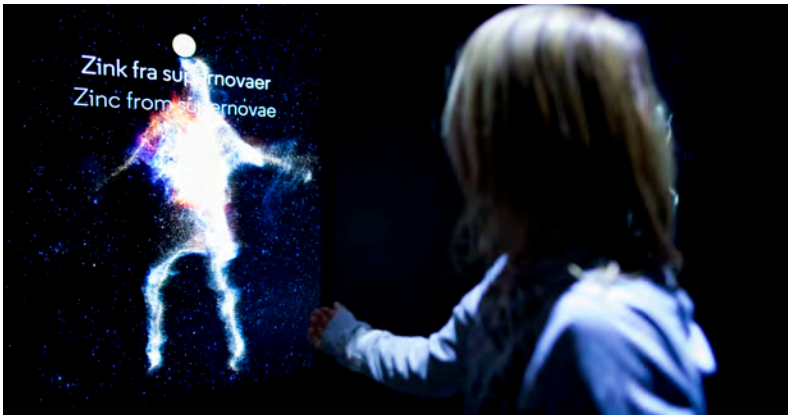

Figure 3: photo of the instillation ‘Introduction’ from the introduction. The Kinect captures the motions of the users, which are then mirrored on the screen, their silhouettes shown in

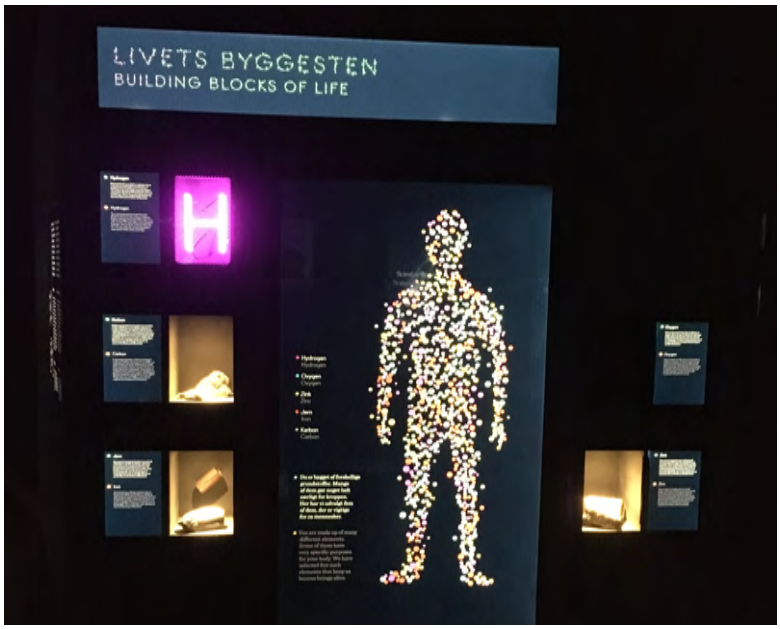

Figure 4: Photo of the ‘Building Blocks of Life’ panels and graphics. The periodic systems were replaced by a focus on only the five important atoms in the key narrative, hydrogen, iron, oxygen, zinc and carbon. The three lit boxes contain a tactile example of iron, zinc and carbon.

Further, this general narrative of ’you are made in space’ not only guided the design of the introduction to the exhibition, but the entire design and framing of the content. The reader may recall that structure of the content was based on the narrative that ’you are made in space’. This narrative was present in the content selection and presentation. Every exhibit represented one part of our cosmic history, and the idea was that the users would be able to ‘select’ the pieces of our common origin. For instance, in the exhibit ‘star formation’, it was explicated that the carbon and iron in our bodies are formed within stars.

Summarizing, during the iterative process, the initial conjecture was deconstructed and reshaped based on the inputs and feedback from the users. The feedback from the users showed that the idea ‘you are made of space’ created a connection to the content. The content selection now focused on what was relevant in the constitution of a human body, and where these elements are found and formed in space. Thereby, the astrophysics content became strongly linked to the users’ own bodies and origins. This connection was embodied in the 'Introduction’ exhibit, where the first things the users meet is an image of their own body on a full-size screen, and the question ‘what are you made from?’ – and finally the answer: ‘you are made in space’. Further, the exhibit was designed so the users were able to build on their prior knowledge, and not feel demotivated by an insurmountable amount of knowledge.

Implications of operationalising postmodern feminism

Using postmodern feminism as a lens pushed the project team to rethink how they would normally organize and structure the content, and whom they were including. The original organisation of the content spoke to users who already had an interest in, and knowledge about, astronomy and astrophysics (Nicolaisen, Achiam & Ibsen, 2020). The intention to find a story that would engage a more diverse group of users required a shift in practice, in which ‘how we normally

do things' was challenged (Risman and Davies, 2013). This awareness led to a new focus, and a new take on astrophysics in the exhibition.

The preliminary assumption that the scientific knowledge surrounding astrophysics was presumed by underrepresented users to be abstract and difficult was supported by the interviews. Further, the interviews also provided evidence that to overcome this barrier, the scientific knowledge had to be put in context (Sinnes 2006, Dancu 2010, Achiam and Holmegaard, 2015, 2017, Nicolaisen and Achiam, 2020), and made relatable to the users' minds and bodies.

Conjecture 2: Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making

This conjecture relates to how the exhibition interactives are designed, based on the content, key message and narrative which had been selected and refined. The reader may recall that the preliminary design conjecture was that social and shared experiences could facilitate cooperation and dialogue, which in turn would promote more inclusive interactions.

How it evolved

I presented this initial conjecture to the designers in the kick-off workshop in the very beginning of the design process, and it was a recurring part of the discussions of the design elements, as illustrated in the excerpt from one of the design workshops:

> (interrupts) but I think that is a good thing as well when we talk about gender because then we could have more people sharing one experience. Or maybe when having something that two people can interact with. That is some of the things you found as well, Line, that that is more gender inclusive as well. *Head of Science Communication* (#39_31 mar 2017)

Here, the Head of Science Communication explicates and actively puts into action the consideration of shared and social experiences. This, in turn, influences the design elements, as exemplified in the following:

> One of the things I have been imagining was, like, say a touch interface, which is, you control [the] interface, and then you control some of the big screen, but … only one or two people will be able to see the interface, so it means that really, we need to put almost *all* the information on the big screen rather than a mixture between the touch screen and the [big screen]. *Lead designer (*#39_31 mar 2017)

This particular idea came to shape the exhibitions, where four of the main exhibits is designed as these interactive stations, or plinths, where users can interact with the contents on a large projected screen through a touchscreen on the plinth (see figure 5).

Figure 5:Photo from the final exhibition showing on of the four interactive stations and projected screen.

Notions of making it possible for two or more people to engage with any given exhibit became an important - and very explicit - part of the schematic design plan proposed by the designers. It was embodied in the design elements, and therefore became an important attribute of the design of the

exhibition (see table 2). Common to all design elements was the awareness of how many people could interact with the installation, and the way in which they could interact. For example, when designing the 'Introduction', the Kinect with the exploded view of humans, the focus was on testing whether the Kinect could allow for dyads to interact simultaneously.

Exploded view of humans using Kinect-technology (one exhibit, three screens)
Plinth with interactive touchscreen projected onto big walls (four exhibits)
Big Bang Moment (20 min. reoccurring take-over of entire exhibition with animation sequence)
Two-person secluded bench in front of animated movie sequence of supernovas (one exhibit)
One-ear headphone in front of talking-heads exhibit (one exhibit)
Connecting-the-dots outro (one exhibit)

Table 2: Table briefly describing the embodiments of the design conjture that Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making

This conjecture therefore has a great influence the design of the exhibition.

> Head of Science Communication: yeah, but then we are talking about that we want to have more people looking at the same thing - the social part, being more inclusive - and then of course size matters (#45a-b, May 31 2017)

The social and shared experience was not explicitly discussed by the user group. Even so, in their talk on prior museum usage, the users described how they would enter exhibitions as a family, but then disperse into smaller groups that changed and alternated throughout the visit, most often in the child/parent constellation.

Examining the importance of the shared experience for users proved difficult in the staged interview setup where they primarily gave their feedback on different visualisations. However, in the observations during the final round of prototype testing, when the users interacted with the exhibits,

it was clear that the plinth/screen setup prompted dialogue between the parent/child on the subjects presented on the screen.

Implications of operationalising postmodern feminism

Summarizing, realising this conjecture entailed a shift in the Planetarium's approach to design, which had produced the previous exhibition ('Space Mission') with a focus on individual, game-like, competitive interactions with the exhibits (Nicolaisen and Achiam, 2020). Ultimately, the design conjecture prompted a rethinking of how to present the story and the content in new ways, and led to an innovative design principle, where all installations were weighed against their ability for social interaction and dialogue.

Conjecture 3: providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways.

Finally, the third design conjecture discussed here represents the development of an initial conjecture about how making room for open-ended questions can allow for an imaginative and emotional approach to science and provide space for 'other' aspects of astrophysics. The conjecture was that making room for open-ended questions could be achieved by providing users with immersive, visual experiences.

This conjecture had clear significance for the users. It was taken up and repeated in the interviews with the different dyads throughout the process. In the first interviews, the significance of visual elements, immersive experiences, architecture and sheer 'wow-effect', were clear themes. When asked about prior museum experiences, the users would often talk of immersive exhibits, and of how the architectural dimension would make them feel. One (Parent M4) exemplifies how entering the planetarium felt like 'an overload of information', which was discouraging.

During the first interview we discussed astronomy and astrophysics in more general terms, the

imaginative power and existentialist qualities of the field were explicit in the users' talk. One interviewee exemplified the existential thoughts provoked by our talk in the first round of interviews, where we focused on a photo illustrating the infinity of space:

> I think – the reason why I don't – now it becomes a bit personal – but the reason why I don't think it is scary is that I…. I think that there is meaning behind it all, I think that there is a 'being' [væsen] behind it all. Call it God or whether you'd like, right? But that is why it isn't so scary for me, because there is a meaning to everything. *Parent M2*

Here, Parent M2 connects our talk on astrophysics and his understanding of, in effect, what he sees as the meaning of life. This is but one example of how the interviews with the intended users often turned to existential questions without being prompted by me. On this basis I therefore advocated for addressing these aspects in an exhibition by allowing room for unanswered questions, and thereby opening up to different views and perspectives.

This conjecture was both an underlying concept and explicitly expressed. It was present in the schematic setup of the room, in the key message, in the visuals chosen, and the large screens that created the immersive experience. Additionally, it was explicitly included in the design. For instance, one feature was the 'blue dot', which is a small sphere on which a still picture of Earth is projected. The 'blue dot' is placed in the ceiling in the hallway leading to exit of the exhibition. The idea was to prompt reflection on our own place in the universe. During the last round of interviews, where the users were asked to give feedback on the physical exhibition, parent M4 reflected:

> Now you think of yourself as part of this system, and being made of it and how we are made, rather than the old school, you know, can you name the planets and our - and all of that stuff. *That* doesn't allow you to think philosophically, because you are trying to remember what you learned in school - that you've forgotten.

The focus on our place in the universe made this parent see himself in a new perspective 'as part of the system', and what was more, it allowed for an alternate entrance to astrophysics, distinct from the 'old school', traditional presentations of the facts and specifics of planets.

Creating a ‘wow’ experience was a part of both the Planetarium Group’s and designer group’s plan for the exhibition from the beginning. This arguably had a commercial perspective, but creating a ‘wow’ experience is also valid from the perspective of creating a more inclusive exhibition. Creating the ‘wow’ experience was manifested in architectural setup of the room. The lead designer used words like ‘immersive’ ‘magical’ ‘mysterious’ to describe the exhibition room in their pitch presentation. To create the immersive experience, the architectural designer created a light lock, separating the exhibition room from the entrance space outside. Then, when entering the exhibition, the visitor would have a 160-degree view of large projection screens with visually compelling content and animations based on computer renderings or real photos, creating the immersive experience.

However, the question of how to strike a balance between on one side, imaginative and artistic representations of science, and on the other, science itself led to an on-going negotiation between the designers and head of communication. One particular instalment, the ‘Big Bang Moment’ (figure 5), exemplifies this ongoing debate.

Figure 6: Photo of the final instalment of the Big Bang Moments, which occurs in 20 min. intervals, and takes over all screen within the exhibition space.

This instalment creates an event that occurs every 20 minutes where the entire exhibition room and all its screens are taken over by an animated visual sequence that illustrates the development of the Universe from the Big Bang moment and until galaxies are formed. Even though scientific descriptions and illustrations of what happened after the Big Bang exist, creating an animated visual sequence that was scientifically correct proved difficult, as many things remain unknown.

> Head of Science Communication: weekly, maybe more than weekly skype meetings in the last month or so, and I've been going back and forth with researchers on these subject to make sure it is [scientifically] correct what we do, as we talked about, with our approach. yes, soo.. #02:15:28-4#

> Lead designer: I guess, I mean, in terms of the overall design approach is that we - from our early discussions, is that the most important thing that we want audience members to come away from this experience with is about a sense of awe, and exactment and inspiration, rather than having learnt x and y fact. So that, as we are trying to figure out, what we can fit in, it is about those things that provide the brilliant moment rather than … having too much information overload. #02:16:21-2#

Here, the lead designer implies that in order to create a 'wow'-effect, the designers need to take a step back and decide how much information should be placed in the installation. This debate is echoed in the user's interviews. Here, users' priorities seem to lie in having an experience that can generate knowledge, but where numbers, facts, temperatures etc. seemed distracting and irrelevant.

> I want to be sucked in to the big bang, I want to be in the middle of the big bang - I don't just want to look at it, I want to be part of it! Parent F3

Implications of the operationalisation of postmodern feminism

Using a postmodern feminist approach and allowing for different perspectives on science opened for a change in practice, where the focus was on creating an experience, and generating a change in the visitors and their self-understanding. Room was made for imaginative aspects of astrophysics, rather than a focus on facts and technicalities, as had been the case in the previous exhibition (Nicolaisen and Achiam, 2020). The design and setup provided room for reflection and different

perspectives the universe and our place in it. As Hein (2010) states the 'wow' is just as important as the 'why'.

But how can we meaningfully talk wow- experiences? Borrowing from Bedford's (2016) understanding of the art of exhibition, and its aesthetic, immersive and imaginative qualities, I deduct how an experience in an exhibition does not necessarily need to be characterised by the transmission of knowledge, but can have merit in the emotions and memories created and in the space provided for a new understanding of self and the surrounding world. As Bedford describes it,

> an aesthetic approach can capture and inspire the deepest kind of personal meaning making, with its potential for transformation (Bedford, 2016, p.16 -17).

I see this as linking with postmodern feminism, in not being focused on uniformity, but rather diversity of experience, which allows for other trajectories into science. In this perspective, reason is not superior to sensation or emotion when it comes to the visitor experience; rather, there is a link between emotion, feeling and cognitive gain (Hein, 2010).

Discussion

The study informing this paper set out to understand *how postmodern feminism can be operationalised in an exhibition design through a design-based research approach, where inputs from users and astrophysicists, staff members and design experts are synthesised in the design of an exhibition on astrophysics.* In the following I discuss what the methodological considerations of operationalising postmodern feminism are, and in the broader terms, what the implications are for exhibition design through the design-based research approach.

Methodological considerations

In this article I've described how I used *design-based research* as a method to operationalise *postmodern feminism*. In this sentence are two discussion points: The operationalisation of feminist theory, and the use of design-based theory in this respect.

Does it even make sense to talk about operationalising postmodern feminist theory? Previous studies have focused on understanding the present structures in out-of-school science education, and how the construct the users, calling for future change of how we conduct formal and informal science education (Calabrese-Barton, 1997, Hein, 2010, Dawson, 2014). Therefore, thinking about how to implement more equitable and diverse science education, both in school (Calabrese-Barton, 1997) and out-of-school contexts (Dancu, 2010) is not by any means a new prospect. Hence, ideas based in postmodern feminism has been used to think about new ways of conducting science education, both in and out-of-school (Achiam and Holmegaard, 2017). I will argue that the research presented in this article is step on the way to understand what the potentials are of implementing the theoretical framings into design.

This leads me to the next part of the research questions. How can design based research work as a vehicle for operationalising such a complex and diverse theory? To unfold this, I want to briefly address the discrepancy between the theoretical paradigms in which the postmodern feminism and design-based research belongs to. This research is set in the critical theorist paradigm, however design-based research is traditionally placed in the interpretivist paradigm. Research in this paradigm views experiences as situated, placed in a cultural and personal context, and findings are therefore not overly generalisable, but exist in specific people, at a specific time, in a specific context (Treagust, Won & Duit, 2014). This general position is shared by the critical theorist paradigm, however here power structures and inequality are in the forefront (Treagust, Won & Duit, 2014). I will therefore suggest that design-based research can be utilised in a critical theorist paradigm *if* and *when* the research and design object is made with a specific effort to give voice to the underrepresented, are aware of the power relationships within the process, the role of the researcher involved and are highly attentive to how the research can promote a positive change.

I argue that in that the effort of connecting theory with practise (Markussen, 2017) and indeed needed (McDonald, 2004, Black, 2010), if we are to continue to re-establish the relevance of informal learning environments, such as museums, science centres and planetariums in society.

Implications of operationalising postmodern feminism in exhibition design

Key aspects of the design were weighed against the conjectures derived from theory and the refinement by the users. This specific and constant attendance to the preliminary conjectures, and to the feedback from the users, significantly changed the exhibition design. As one designer reflects upon the process, the early implementation of postmodern feminism into the design 'changed their mindsets'. Through this paper, I have shown how input from the users was instrumental in (re)constructing the content knowledge in 'Made in Space', and how the users qualified the Design Group's planning of the design. Moreover, the understanding of their prior knowledge on astrophysics and science was key in framing the contextualisation of the topics presented. One key example is how the users' input shaped the 'Introduction' exhibit, which is imperative to understanding the story of the exhibition.

However, the design of the exhibition and the possible interactives was also weighed against other factors, such as technical possibilities and budget. Hence, practice did in cases have higher authority over theory and user input (Bønnelycke et al, 2019). The Design Group and the Planetarium Group had opinions and preferences that were not guided specifically by user responses or theory. These opinions and preferences held power in the discussion of what to include. Thereby, the users' voice was involved in most decisions, but absent from others. This corresponds to the findings of how co-operation is in fact limited in exhibition design development (Davies, 2010). Accordingly, in spite of the increased emphasis on the users (Hooper-Greenhill, 1992) as well as the increasingly frequent instances of user involvement, collaboration and participation in museum exhibition design and development (Simon, 2010, Bønnelycke et al., 2018, Madsen, 2020), the debate on *how* users

should be involved in the development process is still ongoing (Simon, 2010, Bønnelykke et al,. 2018) , and the complexity of the collaboration remains a pressing issue (Knudsen and Olesen, 2016, Mygind, Hällman & Bentsen, 2016).

Outcomes and implications for future design processes

Exploring how to design more gender inclusive science practices has been an ongoing pursuit (cf. Dancestep and Sindorf, 2018Achiam and Holmegaard 2015). As previous studies have shown, the affordances of exhibitions constitute the performable identities made available to the users (Dawson 2014, Archer 2016). In other words, the design of the exhibition form a script, which the users are able to either follow or disrupt (Berg, Oudshorne and Lie, 2002). In Risman and Davies' (2013) framework, the interaction level is where individuals meet cultural expectations that are based on gendered structures. They argue, that as structure act on people, people can also act on structures.

To begin changing the structure of the exhibition design, the institution has to be open for change. I found that having the lens of postmodern feminism prompted the Planetarium to change the process of transforming the scholarly knowledge to the knowledge to be taught (Mortensen, 2010, Achiam and Marandino, 2014). This ultimately changed the structure of the knowledge to be taught, where the focus beforehand content-driven. Now, the view shifted so the users became central and the focus rather became 'why does that matter to you?' (Nicolaisen, Achiam, and Ibsen, in press.).

The focus on designing more inclusive experiences and the focus on users can result in a re-imagining of how to de- and reconstruct scientific content in the effort to design solutions that are inclusive to the underrepresented groups (cf. De Leo-Winkler, 2019; Griffin, 2014, Johnston, 2019, Venkatesan et al., 2019; Kewley, 2019). I will therefore propose that by theory driven and users collaborative design approaches can act as a vehicle to address the challenges facing institutions (cf. Feinstein, 2017). I find support in this argument in Black (2012), who discusses how museums in

general have to transform in order to remain relevant in a changing society, and that this change occurs though an active uptake and involvement of the users and their perspectives (Black, 2012). What I find important here, is that this transformation has to be sustainable. It does not happen overnight, but is a prolonged process, and has to be present in both internal processes and external representations (Kinsley, 2016). However, science learning institutions, such as the planetarium, can no longer take the neutral standpoint, arguing that they are transmitters of value free scientific knowledge, as no such knowledge exists (Haraway, 1988, Brickhouse, 2001, Calabrese-Barton, 1997). They have to consider the context of culture, knowledge and power, and can no longer hide behind the feigned neutrality of scientific knowledge (Janes & Grattan 2019, Janes and Sandell, 2019).

Conclusion

Through the design process of the exhibition *'Made in Space'*, postmodern feminism is operationalised through design-based research. Postmodern feminism informs preliminary design conjectures, i.e. ideas on how to design more inclusive experiences. Through the iterative design process, user collaboration qualifies and informs the design conjectures, which are consistently being reassess and added to design prodcts. The design conjectures embodied in the final exhibition are: 1) Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge 2) Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making, and 3) providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways. The next steps in this research effort is now to study and understand how the design conjectures guide and structure the actual user experience in the finished exhibition.

Concluding, this paper reports on how users and theory informed practice and the design of the exhibition. It proposes that the inclusion and collaboration of potential users from underrepresented groups in the iterative design process as well as insights from theory can act as a mean to address the dilemmas facing the museum world of today (cf. Feinstein, 2018, Black, 2012).

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4.5. [P6] Museums Beyond Neutrality

This article is a position paper, which has arisen from discussions held in our research group. It addresses what we see as important challenges facing the museum world today, and focuses on the roles and responsibilities of museums in society. It was written in pre-corona times, and in these post-corona times, the point about museums moving beyond neutrally is becoming increasingly relevant. During the corona crisis (which we as still in the midst of), museums have been confronted with their position as cultural institutions in Denmark, and they now have the opportunity to reassess and perhaps reimagine their educational and cultural role in society.

As it is a positional piece, it does not rely on empirical data and nor does it answer a research question. Rather, it shows how I have evolved as a researcher through the course of this PhD and exemplifies where I see my research efforts lying in the future.

Note, that this paper chronologically lies after chapter 5 [P5].

Status: in review in Nordisk Museology

Evans, H., J., Nicolaisen, L., Tougaard, S., & Achiam, M. (in review). *Museums Beyond Neutrality*

Museums Beyond Neutrality

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More and more, museums are facing demands of accountability. The days are over when museums could legitimise their place in society simply by referring to the traditional functions of collecting, researching and disseminating (Black 2012, Achiam & Sølberg 2017). Today, urges for museums to clarify their contributions to broader society come from many different sources: governments, who may allocate funding based on an institution's potential to generate financial returns (Rex 2019) or public health benefits (Desmarais *et al.* 2018); historians and indigenous experts, who critique the colonialist structures that enable museums to retain property rights to objects looted from former colonies (Knott 2018, Bakare 2019, Owen 2020); or scholars of cultural history, who demand that the white, western, male gaze prevalent in many exhibitions be replaced with a more diverse range of perspectives (Levin 2010, Robinson 2017, Balle 2019).

We suggest that these and other demands for accountability may be symptomatic of a general frustration with museums' *feigned neutrality* (Janes & Grattan 2019), and therefore an expression of an underlying societal need for museums to declare themselves more openly and explicitly. By neutrality, we mean not being engaged, or decided, on either side of an issue. As we shall argue in this position paper, a neutral position is neither possible nor, indeed, desirable for museums. We develop our argument by drawing on examples from research as well as from recent conversations in the museum community, and conclude by considering the implications of our proposal for museum practice. We focus on science museums (natural history museums, science and technology museums and science centres) because this is our collective area of expertise, but we believe the arguments we make can be applied more widely across museum genres.

Museums are not neutral

First of all, we contend that the institution of the museum is not, nor has it ever been, neutral. Evidence of the value-ladenness of museums comes from many quarters. McLean (1999) says about museum practice:

> Even in the earliest temples of the muses, someone set forth some object for others to experience, and who selected what for whom is the question at the heart of all conversation about exhibitions. The objects may be trophies of conquest, curious things from the natural world, masterpieces, or constructed environments, but embedded in their presentation is material evidence of the presenter's intentions and values (p. 83).

What McLean is referring to here is that the simple act of setting forth objects in exhibitions is not neutral; it is rather an expression of institutional authority intended to prompt certain reflections among audiences. This is so, even though the intentions of exhibition designers are often hidden from public view, or even unconscious (McLean 1999).

The manifestations of museums that emerged in Europe in the 16th century, the *curiosity cabinets* or *Wunderkammern*, explicitly drew on 'exploration' and colonisation of other parts of the world. Today, the collections of many natural history museums in the Global North remain based on objects and specimens collected from former colonies, when the rights of westerners to take them was unquestioned (Norris 2017, Steinhauer 2018). Often, the dissemination of these objects and specimens largely ignores or downplays their provenance (Balle 2019).

Other types of museums have similarly non-neutral roots. For instance, the emergence of science centres in North America in the late 1960s was a response to the perceived success of science in the Second World War, but also a reaction to the successful launch of the satellite Sputnik by the Soviet Union and the resulting worry about the technological gap between the Soviet Union and the western nations. The appearance of science centres thus manifested an urge to create a scientifically competitive public (Ogawa *et al.* 2009) - hardly a neutral or non-ideological position.

Today, reduced public funding for museums prompts them to seek financial support from other avenues. This poses further questions about neutrality, as exemplified by the recent refurbishment of the fossil hall of the Smithsonian's National Museum of Natural History. Rieppel (2019) reported how this refurbishment was made possible by a donation from David Koch, an American multi-millionaire. With his brother Charles, David Koch was a

key funder for climate change denialism, and the refurbished fossil hall that he helped fund has been accused of whitewashing the present climate crisis by making it seem part of a natural continuum, rather than a problem caused by human activity (Little 2015). The choice of downplaying or ignoring evidence of anthropogenic climate disruption in an exhibition that addresses climate is a curatorial decision, certainly, but not a neutral one.

To be sure, we are not seeking here to condemn the use of private funding in the development and maintenance of museum practices, although it has been argued that museums should completely avoid funding from certain sponsors (cf. Lyons & Economopoulos 2015). We acknowledge that donations and funding from private organisations are a fact of life for many, if not all, museums. Nor are we advocating that those institutions whose genealogy is intertwined with values and ideology should suddenly cease to exist! Our critique here is of positions that tend to *obscure* the ideological foundations of museums and their practices.

Neutrality is not possible

Although the examples we have given in the preceding can be seen as *proof of existence* of non-neutrality in museums and their practices, we would like to take our argument one-step further. We claim that a neutral 'view from nowhere' (Haraway 1988) is impossible, because such a viewpoint simply does not exist. Even though objectivity has historically been an important part of the self-image of science (Reiss & Sprenger 2017), science is not culture-free, and cannot produce culture-free, ahistorical knowledge (Brickhouse 2001). This means that attempts to maintain a disinterested and objective position on science by disseminating just 'the facts' flies in the face of research that shows how science is, among other things, gendered, raced and classed (for example Harding 1986, Code 1991, Leslie *et al.* 2015, Wong 2016). In the words of Jillian Steinhauer, "claiming not to take a position is actually a way of taking one - it means supporting the status quo" (Steinhauer 2018).

Even so, the 'enlightenment' view of science that positions it as objective, disembodied and universally true has long characterised public engagement efforts (Davies 2014). This is a problem, because the enlightenment perspective appeals to only a fraction of the public: typically middle-class, well-educated people. This results in feelings of being excluded among many members of the public who are left out, for instance those from lower socio-economic groups, from minority ethnic groups, older adults, and those living

in rural areas (Garibay 2011, Dawson 2014, OECD 2018). We thus contend that not only is neutrality impossible, but also that feigning neutrality can be harmful or seem hostile to a wide diversity of publics.

(Feigning) neutrality is not desirable

Finally, we suggest that rather than trying to conceal the ideological, political, institutional and cultural conditions that shape their practices, museums should openly disclose those conditions, as well as their own motivations for selecting, displaying and engaging with certain aspects of science. We argue that rather than risking their reputation as trusted communicators (cf. Janes 2013, Rodegher & Freeman 2019) or alienating their funders (cf. Janes & Sandell 2019), this disclosure can *maintain and strengthen* museums' credibility. This is because even though feigning neutrality may seem to justify a museum's focus on telling the facts and effectively absolve it from having to consider the implications of science for society, actually the feigned neutrality position just places this responsibility squarely on the visitors' shoulders (Rodegher & Freeman 2019). This displacement of responsibility seriously undermines the educational mission of museums (Janes & Grattan 2019) in a climate where they are increasingly being called upon to justify themselves. In other words: if museums, the stewards and repositories of scientific thinking (Janes & Sandell 2019) cannot engage the public in reflecting on how science and society mutually affect each other, who can?

On a positive note, the growing movement among museums to create equitable and inclusive experiences, decolonise their collections, and address social justice seem to be evidence of a commitment to jettison notions of neutrality, and embrace a more transparent point of view. We encounter international examples of this movement, including the newly established museums of climate change in Hong Kong and New York, or the Museum of Tomorrow in Rio de Janeiro. We also encounter more local examples of this commitment, as exemplified by this comment from a museum professional close to us:

> The activist tendency among museums is, as I see it, on the rise. Museums give their points of view on current debates, and use their position to suggest solutions to on-going societal issues. We witnessed this, for instance, in connection with the election of Trump, when several American museums exhibited works originating from the seven countries Trump banned immigration from.

At our museum, we talk about how this is a tendency that cannot be overlooked in our present society and the time we live in. Moreover, that it helps create trustworthiness in museums when they take a stance based on a professional rather than a political point of view.

We believe the brief examples provided here represent different ways for museum professionals to respond to a broader societal need for museums to make their purposes and intentions explicit. In the final sections of this text, we offer principled suggestions about what these responses might look like from our perspective.

What might non-neutrality look like in museums?

Located as we are in academia, we do not claim to have in-depth expertise in the detailed workings of museums. In the following, we limit ourselves to briefly remarking on the general features of what non-neutrality could look like across the museum pillars of collections, research and dissemination. We are well aware that these suggestions are slightly removed from everyday museum practice, and require operationalisation. We hope the museum professionals who read this text will consider these suggestions in the constructive spirit in which we have attempted to write them.

Collections. Museum collections have been likened to the soul of the museum, or its reason for existing (Alberch 1994). Although the asymmetry between those who collect and those who provide the specimens has gradually been replaced with much more equitable practices (Norris 2017), other problems related to the sustainability of collections have emerged. In particular, consumerist and materialist aspects of collecting have come to the forefront of discussions, given the increasing costs of maintaining and expanding collections (Bradley *et al.* 2014) coupled with sometimes vague claims of preserving heritage for posterity (Allmon 1994; Janes & Sandell 2019). For museums, non-neutrality could consist of being explicit about how the accumulation of specimens and objects (and the related expenditure) can help us understand the problems we face as a global society, such as the biodiversity crisis (Suarez & Tsutsui 2004) or climate change (Robbirt *et al.* 2011), or serve as repositories of technological memory as we search for solutions to modern-day problems (Janes & Sandell 2019).

Research. The scope of present-day museum research goes well beyond the descriptive classification that characterised early work. New analytical techniques, digitalisation and

other developments has multiplied the contributions of museum research to society (Howarth 2017) where it provides crucial insights on public health (including pandemics), agriculture, habitat loss and many other problems (Suarez & Tsutsui 2004). Current museum research thus distinguishes itself from the 'value-free' stance that has been a historical part of the self-image of the natural sciences (cf. Reiss & Sprenger 2017). Declaring this non-neutrality could consist of explicating what sustainability values guide the museum's research, and how those values shape its identification of problems, formulation of research questions, and findings (cf. Schneider *et al.* 2019). Whether those findings are ultimately used to argue for changes in government policy or to promote informed civic engagement (Achiam & Sølberg 2017, Howarth 2017), we claim that transparency about how they came about will strengthen the credibility of the museum.

Dissemination. Finally, a science museum's dissemination activities are its most immediate interface with the public, and thus where a non-neutral stance will have the greatest impact on public perception. Just like museums' collections and research activities have changed over time, so have its dissemination activities, perhaps most obviously in the case of exhibitions. Here, early communication models intended to show the scientific primacy of the object have been gradually replaced with models that acknowledge the role of the visitor's prior knowledge and experiences (cf. Achiam 2016). Today, the most progressive exhibitions are making important steps towards fully embracing and declaring the cultural diversity and significance of the displayed objects and their provenance (Blond 2017). Therefore, non-neutral exhibitions in museums are those that openly question authoritative or canonical accounts of science, and engage their communities in negotiating the meaning of scientific objects and practices (Sandholdt & Achiam 2019). This engagement can take place in the design phase through co-curation or co-development processes with relevant publics (for example indigenous communities or people impacted by climate change, Anderson & Hadlaw 2018) and by explicitly including and contextualising the multiple voices of those publics in the exhibition (Blond 2017).

Conclusion

In this paper, we have argued that museums have never been neutral, nor is it a desirable position. In fact, we believe that an explicitly non-neutral stance presents the museum community with an opportunity to clarify their many contributions to broader society, thereby increasing their relevance and inclusiveness to the public. We thus invite the community of museum professionals to consider the day-to-day and long-term implications of a museum beyond neutrality.

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PART 5

5. Final analysis of 'Made in Space'

This chapter will describe what the exhibition existed in the 'real world'. What happened after we opened the exhibition in February 2018, and when the actual users of the planetarium began to explore the exhibition?

5.1. Introduction

In this chapter I will address how the exhibition Made in Space was received by the actual users of the Planetarium. In other words: do the embodied design conjectures on how to operationalise postmodern feminism in exhibition design result in a more inclusive exhibition?

As the reader will recall, in the co-design process of Made in Space I constructed a set of initial design conjectures that guided our approach to the structure of the content, the key message and to the design of the exhibition. These conjectures drew on previous research efforts in designing gender inclusive out-of-school science educational practises. During the development of Made in Space these conjectures were continuously refined and rephrased based on the feedback and input from the user groups, who were presented with visualisations, prototypes and texts. The plans for scientific content, design, and formulation of text were therefore formatively evaluated throughout the design process.

Therefore, in the case of this chapter, I am not thinking of the evaluation as resulting in summative and finals answers. Rather, it is a final analysis of the implementation of the embodied design conjectures, further refining and concretising the design conjectures based on actual user experience. I therefore see it as being one further step along a continuous road, rather than an evaluation separate from the development of the exhibition. Even though the results from this final analysis will not be incorporated into a re-design of the exhibition, the results will point to how these design conjectures can be formulated as design guidelines for future exhibition work. Hence, this part of the thesis will answer the third research sub-question:

> **[RQ3]** How are the conjectures of the various exhibition developers, regarding astrophysics, astronomy, and the visitor experience, embodied in the exhibition and enacted by visitors to the exhibition? Specifically: how are the gender inclusion aspects of the exhibition realised in the visitor experience, and what are the implications of this realisation for the design of inclusive exhibitions?

I have therefore chosen to examine inclusion-related aspects of users' interactions with and dialogue about Made in Space, using the patterns found in previous research, e.g. Dawson, (2014a), Archer et al. (2016a),

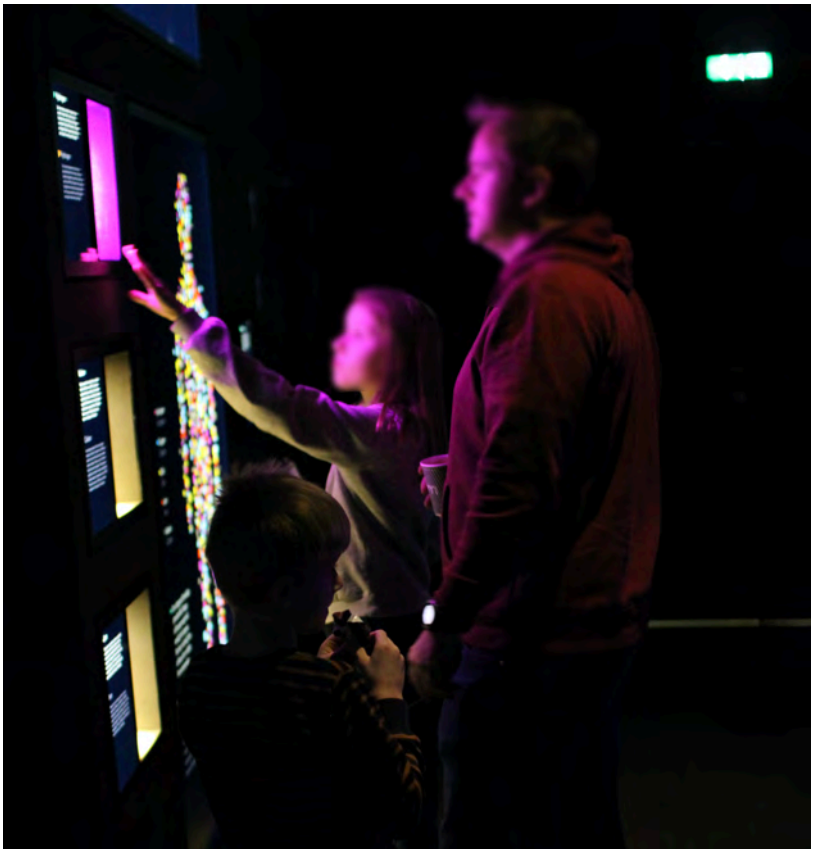
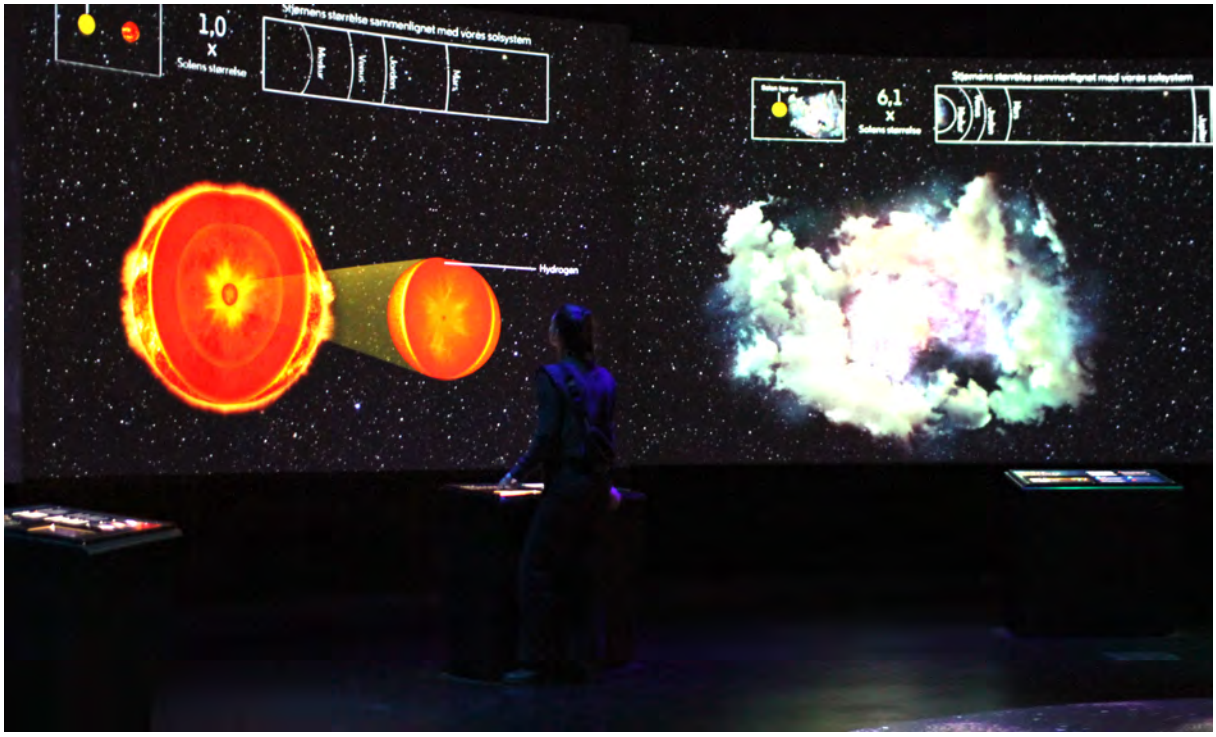


Figure 16: Photos of the ‘Your Cosmic History’(above) and ‘Building Blocks of Life’ (below) from The Introduction.



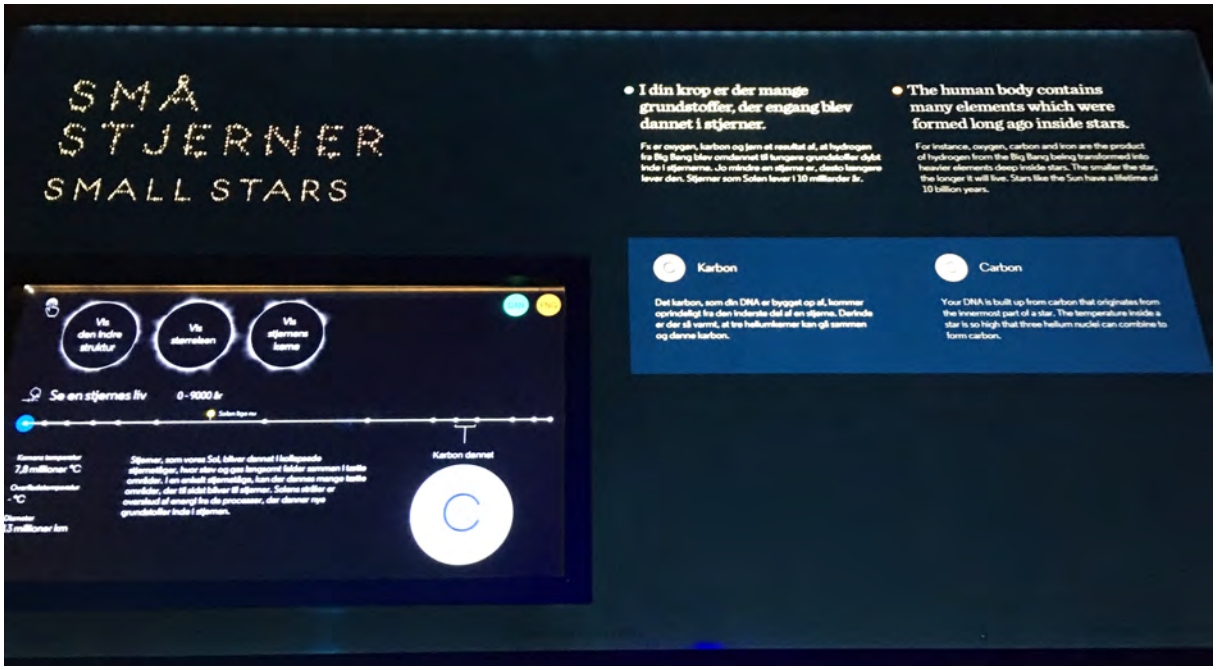


Figure 17: Photo displaying the ‘Small and Medium sized Stars’ exhibit, the touchscreen and text on the interactive station. The interactions with the touchscreen is projected up onto the large screen.

and Haden (2010) as an analytical lens. To do so I will first analyse how the users interacted with the embodied design conjectures from [P4], and discuss how these compare to other exhibitions. I will continue to stay within the design conjecture nomenclature within the design-based research framework in science education.

5.1.1. The design conjectures, their embodiment, mediating processes and intended outcomes

When I talk about design conjectures, I talk about how we assume a certain design element will be received by the users, how they interact with it and what the outcomes of this interaction will be. I build upon William Sandoval's concept of design conjectures, which describes how a specific assumption about how to support a desired outcome (the *design conjecture*) is embodied in a design, how that physical design prompts certain interactions (or *mediating processes*) required to produce the desired outcome, and how that desired outcome, is in fact, produced (Sandoval, 2014). Thus, here I investigate the mediating processes and related outcomes prompted by the embodiment of the design conjectures developed in [P4]. In the case of Made in Space, design conjectures are embodied in specific designs of interactives, e.g. in '*The Introduction'* and the *'Small and Medium Sized Stars'* (See figure 16 and 17). These designs prompt mediating processes, in this case social interactions, collaboration and dialogue between users. Finally, the desired outcomes are the ways these mediating process act on and affect the users: Do the visitors experience what we expected they would? How do they reflect on the experience and on themselves?

In [P4] I focussed on three main conjectures, namely 1) Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge 2) Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making, and 3) providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways. All of these design conjectures are deserving of further study and evaluation; however, for the sake of clarity and brevity, I focus on two conjectures that were essential in the process of thinking about gender inclusive design. In the following I dwell briefly on these two conjectures to remind the reader of their characteristics, and explicate what I consider to be mediating processes and desirable outcomes. I will distinguish between two different kinds of outcomes: learning outcome and the broader outcome. Each exhibit did have a specific desirable learning outcome, but the conjectures also had broader, and perhaps 'fuzzier' intended outcomes.

Design conjecture 1: Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge

In the development of Made in Space, one of the key design conjectures was related to the importance of creating connections to the knowledge to be exhibited, and providing context and relevance for the users. In other words, how can we help visitors make a connection with abstract knowledge? How can we present astrophysics in ways that do not rely or depend on numbers, facts or technicalities? From an earlier study (Nicolaisen and Achiam, 2020 [**P2**]) we know that Planetarium had previously exhibited astronomy, astrophysics and space science in ways that promoted individuality, focussed on facts and numbers, and assumed a high level of prior knowledge and interest. In contrast, we wanted to promote shared experience, deeper understanding, and meet visitors at their level of knowledge and interest.

In the case of Made in Space, we wanted to connect the content knowledge with the users' emotions and bodies (Nicolaisen [P4]). Therefore, the key message, or the narrative, of the exhibition became 'you are made of the Universe'. The idea was that by creating a clear link between the users, their bodies, and their conceptions of their ultimate origin, we would create a connection and make the abstract and distant Universe become closer and more relevant. This conjecture is central to the entire story driven design of Made in Space, and it is embodied in several aspects of the exhibition (See table 2).

Design conjecture 2: creating shared experiences allow for collaborative interaction and the social construction of knowledge

The second design conjecture I discuss here is the assumption that creating shared and non-competitive experiences would decrease the threshold of engagement, and provide a 'safe' space to interact (Achiam and Holmegaard 2015, 2017; Dancestep and Sindorf, 2018; Nicolaisen and Achiam, 2020; Sinnes, 2006). Further, as the target group of the exhibition is families, this conjecture draws on knowledge on how learning processes occur in social interactions (cf., Dierking, 2013; Falk and Dierking, 2000) and how families act in museum settings (Allen, 2002; Tenenbaum and Leaper, 2003). Based on this work, social and shared experience are assumed to make space for a collaborative and elaborating dialogue, where joint meaning making can occur (Haden, 2010). This design conjecture ultimately became a guiding principle in the design process, in that all design elements were weighed against how many people they could engage at the same time (see table 3). The most explicit embodiment of this design feature, and a dominant design feature in the central exhibition area, is the exhibit *'Small and Medium Sized Stars'* which comprises a plinth and a large projection screen.

Design conjecture	Embodiment	Mediating processes	Outcomes
Link between body and universe makes people want to engage with abstract knowledge	In 'Your Cosmic History' the Kinect sensors the users motions and their own body is projected onto the screen	Use of own body, playful and shared interaction, linking connection between users and the universe	Makes the the abstract knowledge more tangible. The link between the universe and users makes them understand themselves and the world in new ways
	Buliding Blocks of Life' exhibit is graphic describing the atoms, presenting tactile objects (rock specimens) as well as describing where in the human body they play a role	The focus on few atoms and their link to the body as well as the tactile experience allows the users to link the abstract notions of atoms to a more concrete context	
	Throughout the exhibition, the focus and key message is explicit in the text as well as in text boxes using the same colour coded symbol of the atoms as in the introduction	These keep the focus on *why* the users are engaging with the exhibit, and act as reminders for the general story	

Table 2: Examples of the embodiments of design conjecture 1 in the exhibition design

Design conjecture	Embodiment	Mediating processes	Outcomes
Creating shared experiences allow for collaborative interaction and the social construction of knowledge	The plints, i.e. the interactive stations with touch pads, and projection on the large screens	The plinths will allow for more to interact together, and interact with the touchpad and as onlookers on the screen, this will aid collaborative social interaction and the social construction of knowledge	The shared experience, the social collaborations and dialogues helps the users together make meaning in various ways of the abstract knowledge
	Kinect, with more people at same screen	The Kinects allow for users to use their bodies, play, interact tighter	
	The Big Bang Moment, were the entire central exhibition area is taken over by a visualisation of the Big Bang	Awe, wow-effect, and shared experience for all the users in the exhibition at the same time	
	Bench with room for two adults, or one adult and two children, in front of Supernova film	The aim was to create a space for a shared, but also enclosed and more calm experience, where two- three people could watch the visualisation together and talk about the contents	
	The afterword ‘What is Life', where the users enter a room of mirrors, and dots of the same colour coding as in the rest of the exhibition gathers on their bodies	The users are met with the screen, and as they read the text, they see the coloured dots representing the atoms gather on themselves and others, intending to remind the users of that their bodies are connected to space.	

Table 3: Examples of the embodiments of design conjecture 2 in the exhibition design

5.1.2. The exhibits

As discussed in the preceding, I focus here on two specific exhibits that were part of Made in Space, and that embody the two main design conjectures described above. The chosen interactive are the *'Introduction'* (A01a-c) and *'Small and Medium Sized Stars'* (A07).

The design conjectures embodied in The 'Introduction'

The aim of the 'Introduction' was to introduce the key message of the exhibition, namely that the visitor is 'made of the Universe'. It is divided into three exhibits *Ingredients of life* (A01a), *Your Cosmic History* (A01b) and *Building-blocks of life* (A01c) (See figure 18).

Ingredients of life is a small introductory text and a picture. The graphic starts with a quote from Carl

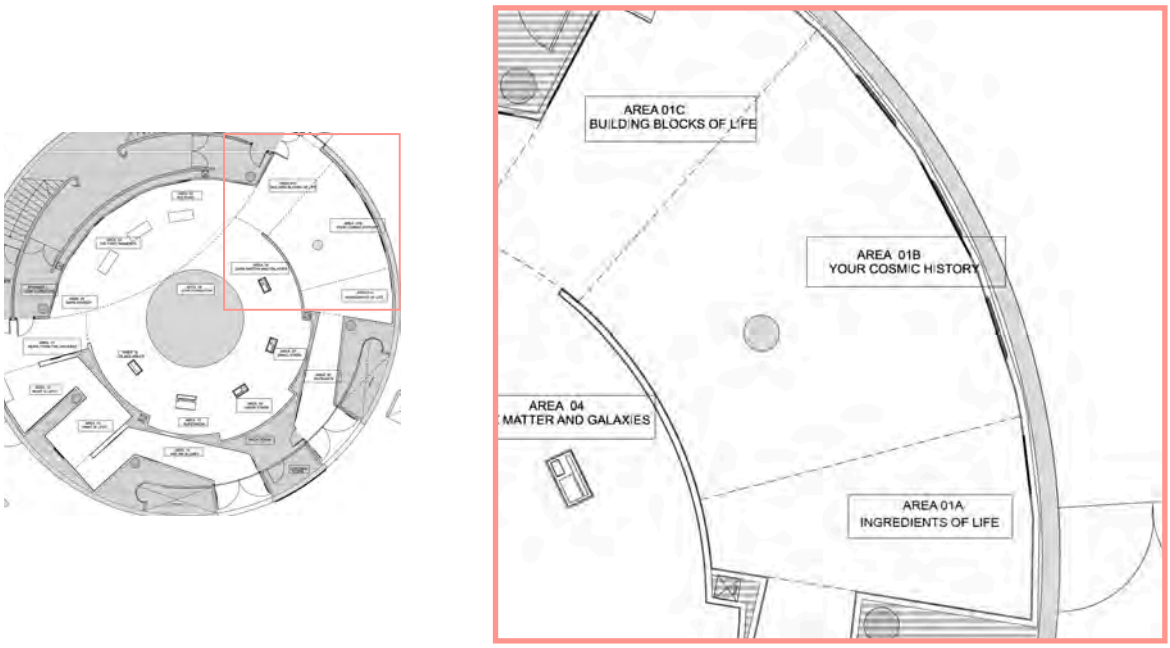


Figure 18: The left show the map of the entire exhibition room (white areas) and the pink frame illustrate where *The Introduction* is placed.

Sagan: 'If you wish to make an apple pie from scratch, then you must first invent the universe', and further reads that the same is true for humans; that we are all made of ingredients created in space. *Your Cosmic History* is an interactive installation consisting of three screens with Kinects, which is a motion sensing input device. By the use of infrared light, it can detect of how the users moves in front of the screen, and visualise these moments on the screen in real-time. A set of footprints are on the floor in front of each screen, indicating 'stand here'. Before the screen is activated, it reads 'what are you made of?'. As soon as the users step in front of the screen, their outlines show up on the screens as silhouettes of starry dust as well as small colour coded dots indicating different elements. Then, the users' on-screen bodies are 'exploded' and the text again reads 'What are you made of?'. Next, the atoms are introduced with a distinct colour as well as a visualisation of the process forming them (e.g. supernova). Hydrogen from Big Bang (pink), Carbon from small stars (grey), Oxygen from large stars (blue), Iron from large stars (red), and Zinc from

supernovas (yellow). When each element appears, the silhouette of the user's body is formed by coloured dots corresponding to the colour of the element. When all elements are presented, the users body explodes one more and the text read 'You are made of the universe'.

The next exhibit component, *Building-blocks of life*, is an illustration of a human body with the colours corresponding to the elements, as well as a small description of each element and where it is found in our bodies and what role it plays, e.g. iron in our blood. Coupled with these descriptions is a small display or box where a physical representation of each element is presented (rocks, a steel tube) and can be touched by users. The gas atoms are represented by their chemical symbol shaped in coloured neon tubes. The final part of the 'Introduction' is a graphic with a short description and illustration of what an atom is.

The Kinects were tested so that they could include several users at the same time, thereby having a shared experience, in correspondence with design conjecture 2. Further, the three Kinect installations were placed next to each other, to inspire onlookers, and prompt shared experiences, and thereby decreasing the threshold for engaging. It was assumed that the **mediating process** would be that the users would playfully engage, use their bodies, read the screen and discuss the content. These mediating processes were assumed to create a connection to the visitors' selves because they would use their own body in the interactive.
The **intended outcome** of the 'Introduction' was that the users would see a connection between themselves and the universe, and would place the presented knowledge in context and find it relevant to their own lives (see [P4]). It was issued that this in turn would motivate them to continue to explore and engage with the exhibition, for them to feel able and adequate to do so, and ultimately understanding themselves and the place in the world in new ways (Nicolaisen [P4]). The experience was thus intended to act as a presentation of the key message by creating a link to the user's experienced self. The **intended learning outcomes** where thus that the atoms in our bodies are made in the universe. Further, the 'Introduction' where also to give the users a basic understanding of what atom are, presenting a tactile representation of the elements on earth, as well as where in the body these atoms are (mainly) used. The colour coding scheme used for each atom in the exhibition was also introduced, aiming at making it easier to connect the content in the central exhibition area with the key story.

The design conjectures embodied in ' Small and Medium Sized Stars'
The *'Small and Medium Sized Stars'* interactive is an example of the exhibits designed with an interactive station, called the plinth, and a large projection screen, controlled by the touch screen on the plinth in front (see figure 19). There are three such exhibits in *Made in Space*. On the plinth is a graphic with the headline 'The human body contains many elements which were formed long ago inside stars'. Further, there is a text box with the symbol of the element Carbon (as introduced to the user in the 'Introduction') as well as a description of where in the human body it is found. On the plinth is also a touchscreen showing a timeline with the life cycle of a small star, from birth in the gas clouds in the nebula to its death, when its nuclear reactions fade out and the star forms a planetary nebula. Using the touch screen it is

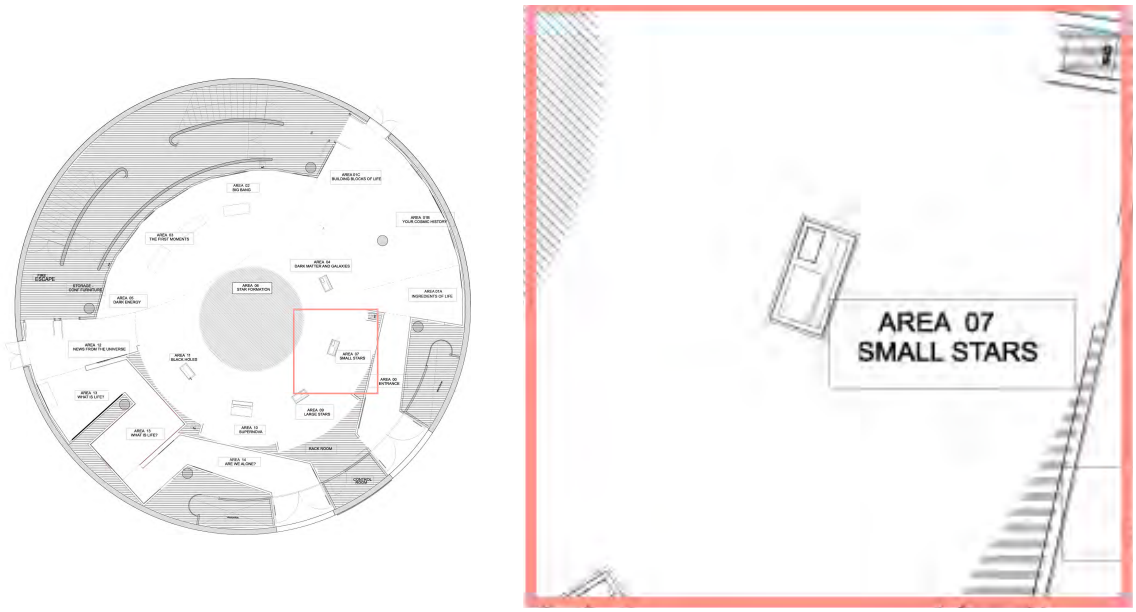


Figure 19: Schematic map of the entire exhibition is shown on the left, and the *Small and Medium Sized Stars* interactive station and screen is shown with the pink square.

possible to scroll through the life cycle and read the text associated with each phase of the star. On the large projection screen there is a visualisation of the small star at the specific phase. Additionally, there are three buttons in the upper left corner, marked *Show inner structure, show core, show size.* When chosen, the visualisation would show the inside of the small star, and the atoms or elements formed in the core and crating layers in the star. When a new atom or element would be formed in the core, it appears on the screen, written out. When size is chosen, a bar on the top of the projection screen shows how big the star is compared to our sun, and the inner planetary average orbits (see figure 17). On the plinth touch screen is a round grey dot with a C, the colour coded illustration of a carbon, which clearly indicates where in the life cycle carbon is formed in the star - from where the carbon in our bodies originates.

The design of the plinth and large screen was intended to prompt the following **mediating processes**: that two or three users would interact with the touch screen together, and that additional users would simultaneously view the content on the large projection screen. Thereby the intention was for several people to join in the experience, promoting dialogue. The **intended outcome** was that the user groups would find meaning together, through joint meaning making (cf. Haden, 2010). The **intended learning outcome** is for visitors to realise that our sun is a star, and that stars have a life cycles and are not static objects. Further, the star is born out of a nebula, as the star evolves, processes within the star form different atoms, one of these being Carbon. As the star dies, these elements are flung out into space, and become part of the big space 'ecosystem'.

5.2. Method

I focus on the exhibition as being one of many social contexts which citizens find themselves in, and I expect to discover users' encounters and impressions of the exhibition in question, situated in a specific context at a specific time. Accordingly, I began my evaluation by conducting a pilot study to understand how the users act in the exhibition, and thereby to find a suitable method of this final analysis.

5.2.1. Pilot Study

The user observation pilot study was conducted in April 2019 during the Danish Easter holiday, where the Planetarium traditionally has a high number of users. The aim of the user observation was to acquire a more in-depth insight into how the users interacted with each other and the exhibition, to use for planning the actual data collection. I was present in Made in Space, observing and taking notes on users' interactions for two separate days, three hours each day. The pilot study gave me an initial and a general understanding of users' movements, interactions, and dialogue; most importantly, I gained an impression of the patterns of families' interactions. Specifically, I found that the plinths did allow more people to engage together, and they promoted dialogue between users. The users looked at the touchscreen, investigated the content together, and pointed to and discussed the processes shown on the large screens. I found that the Kinect screens in the 'Introduction' led to playfulness between family members, and that the interactive on central star formation [A06] prompted shared experience, playfulness. Even so, I am not sure I observed meaning making, explicitly. Because I was interested in studying those exhibits where the users would spend a significant amount of time, and with which the most users would interact during their stay in the exhibition space, my observations guided my decisions on which exhibits to focus on in the data collection.

Based on the pilot study I decided to combine the unobtrusive observations that allowed me to understand naturally occurring interactions with the more intrusive methods of walk-alongs and exit interviews. The walk-alongs were a way for me to gain insight to the in-situ experience and the mediating processes prompted by the design (i.e. cognitive gains, self-reflection, experiences, dialogue, thoughts and views). The exit interviews were a way to access users' reflections and attitudes immediately following the visit.

5.2.2. User observation

Observation is defined by an observer who observes life unfolding naturally at a specific time in a specific place (Schatzman & Strauss, 1973). Some of the first visitor studies in museums were based on unobtrusive observation of users, often resulting in maps of users journeys (Macdonald, 2006). To observe without interference can arguably provide information about the natural ecology of an exhibition and user

experience. This being said, the observer is not an objective recorder. Therefore, observation is not neutral (Warming, 2005, p 146). Even so, the method can give insights into what transpires where and to whom. What are the journey paths of the users? Which exhibits do they engage? Are they active or passive? How do they interact with one another? Do they speak; is there silence or dialogue? Do they exclaim, yell, scream, laugh?

Why I used it

In this case I found the observations of specific groups (families) entering the exhibition space to provide a rich source of information that seemed unaffected by my interference. I was able to study how the users acted in the physical space, and therefore to respond to some of the design conjectures related to physical and spatial design, such as whether the plinths allowed for multiple users, how the users interacted with the installations and how the users moved in the space.

Observation procedure

I carried out both more general observations, where I would sit quietly in a corner of Made in Space and make notes on how people interacted with the exhibits, and specific observations of eleven families. For the specific observations, I would choose a family once they entered the exhibition, and make a note of the time they entered. I would note their route through the exhibition, whether there was distinct talk or exclamations I could hear, and how the family interacted with the exhibits. Every time I had carried out a few specific family observations, I would retreat to the office to write a so-called experience map (Table 4) for each of the families, inspired by Skov, Lykke and Jantzen (2018).As discussed in the preceding, the user observations provide a detailed description of how the users use the exhibition space, but they do not shed light on the kind of that dialogue occurs, nor do they reveal the users' thoughts on their experience (cf. Kusenbach, 2003). Therefore, I used walk-alongs to get an insight in how people talked, what they thought, and how they made meaning of the exhibition.

Observation of group 2 (G2) 10.02.20 15.37-16.06	**Participants** W + M + B (app. 10)
Themes **Rhythm and route: (where do they go, how much time is spend at each exhibit)** A01b - A01c - A06 - A04 - A07 **Collaboration: (e.g. who takes the initiative, who talk to who)** W explains and encourages B, B tries to engage M, M a bit more disengaged (spend time on phone), but then begins to engage **Dialogue and sense making: (e.g. is there a dialogue, is it reading aloud, is there a sense/meaning making, is it passive)** W mostly reads texts and introductions and explains to B, M also engage in conversation. They are focused (mostly W) on B, on mediating the content to him. **Approach: (do they read, do they just push buttons, do they engage?)** They engage, read, and are active **Movement: (do they play, dance, stand still)** W+B play, dances, makes stars together. However, at some point when dad is on his phone he stands aside from the rest of the family. **Main moods: (happy, disengaged, relation to interviewer)** Happy, relaxed	**User journey** mom, son, dad, dances in intro, playful, W moves over with B to the atoms, reads and explains to B, soon, B wants her to follow him into CEAcentral exhibition area, he runs in to play on Star Formation (A06), W reads text, she walks onto interactive, stands still W: Look, I formed a star! B: Dad, look, look what I am making! Stars are forming around them B: Look, Look! They play together W: Lets all stand together. They hold hands, form a circle B: Look, we made a blue one! BB begins - they move close together, Dad (M) explains briefly what they just saw. B continues to play on A06. W+M looks on, and wait for him, but begin to engage themselves. Mom goes over to A04, son joins W: It is pretty cool, you can control the universe, want to try? M on phone, B tries dark matter, M walk over to Small stars, invites B over M: This is the sun They don't find the 'see inside the star' 'See the core' button right away, but stands scrolling for a while, pointing and talking. W reads handout, and call them over, they are going to find where the are seeing the movie (perhaps the one starting 16.30)

Table 4: Sample of experience map as the based on Lykke et al. (2018).

5.2.3. Walk-alongs

Walk-alongs are a method where the interviewer follows participants as they move through a space, and take part in the interactions and experiences as they occur. The concept is derived from urban design planning (Lykke and Jantzen, 2013), however walk-alongs have also been employed in visitor studies to understand user experiences (Skov, Lykke & Jantzen, 2018). Walk-alongs thereby combine the in-situ, physical mediation of the 'space', and the internal negotiation in real time, not retrospectively. It gives the researcher insight in the constellation of the experience in time and space (Skov, Lykke & Jantzen, 2018).

Why I used them

As mentioned, I view the design conjectures that guided the development of Made in Space to entail certain mediating processes. This means that for instance the plinth, i.e. interactive stations, with a touchscreen that links to the projected interactive, was not just designed to engage several people in interaction, but also represented an assumption of how people would socially interact and the implications of this for their experience. Therefore, I needed to understand the mediating processes as they occurred, as well as the outcome of them. The walk-alongs were the means for me to gain that understanding. I focused on the two exhibits described above, The 'Introduction' (A01a-c) and 'Small and Medium Sized Stars' (A07) as my target for the walk-alongs.

Walk-alongs procedure

I stood next to the entrance to Made in Space wearing a Planetarium lanyard with a card identifying me by name and affiliation (PhD-student at the University of Copenhagen). I had my notebook in hand as well as a recorder. I approached groups or families with children that I judged to be about 12 years old. I asked whether they were about to enter the exhibition, and if they were, I asked if I could join them, giving them a brief introduction to the project. This introduction clarified that I was evaluating the exhibition, but did not mention the inclusion or gender perspectives. I asked that they act as they would normally, but explained that I might ask them questions along the way. Finally, I requested permission to record the conversations that took place. If they agreed (3 out of 17 declined), I followed them to the 'Introduction', where most visitors began their visit. I would open the conversation by asking demographic questions such as age, and the occupation of the adults.

In the beginning of the walk-along I would focus on making them comfortable with my presence by acting professionally but not authoritatively. If they asked me questions related to astronomy, i.e. used me as a guide, I would let them know that I was not an astronomer and probably knew less than they did on the matter. An example of such an exchange from the date reads:

> Boy 13: [addressing me] So nobody has found out what it would look like if we take the iron out of the blood or what?

Researcher: I actually don't know, I'm not physicist or biologist, but that it is a really good question for you to investigate.

I would laugh along with the children, sometimes participate in the activities, and generally try to be a natural extension of the group in order for my presence to be as unobtrusive and comfortable as possible.

During the walk-along I would observe and listen, audio record, and take notes both on the participants' exclamations and dialogues, and on the way they moved and interacted. The notes were cross-referenced to the audio recording by checking the time on the recorder (which also gave me insight into how long participants would stay at an exhibit); I used the codes from the design scheme, e.g A01b, to track where the participants were. An example of such a note reads:

A01a: Family plays at intro, dad reads aloud, while the kids dance.
A01c: Dad reads aloud from text (2.41), while boy touches the stones.
Boy "I am iron" (02.57) Mom explains DNA to daughter, while son says "look over here", father follows him, they start to interact with galaxies, Dad explains something on the screen to son, points to screen, daughter comes over, are not allowed to press button. She stands with them shortly, then walks away.

When I was unsure about an interaction, I would prompt the users to speak aloud about their experience to articulate their thoughts and views, and to comment on their experience as it happened (Skov, Lykke & Jantzen, 2018).

They stand in front of A01a:
Researcher: can I ask about what you are experiencing right now?
Girl 8: it is really cool that you find out what there is in you body - I hadn't thought about that.
Researcher: what is it that is cool about it?
Girl 8: it is just that then you know what you are made of and where it comes from.

I used several types of questions. One type prompted the participants to verbalise their experience (e.g. what is happening now?), another prompted them to articulate their viewpoints (e.g. why was it fun?) and a third variant sought to gain insight in their reflections (e.g. what did that make you think?). The way the participants answered often reflected their activity level at the exhibition. For instance, participants who seemed more quiet or shy would often also answer briefly, e.g. 'it was fun'. In such cases I would follow up

with additional questions, such as ‘what made it fun?’. Other participants were very active, and often also very vocal along the walk-along; these participants tended to give longer answers.

After following the participants through the exhibition, focussing on the 'Introduction' and the 'Small and Medium Sized Stars' exhibits, I thanked them and said ‘I will now set you free so you can experience the rest of the exhibition by ourselves’. Finally, I asked them whether they were interested in meeting me just outside the exhibition afterwards for a brief interview. All participants agreed. When possible, I would then sit down quietly at a distance to discreetly observe the rest of their visit in the exhibition and take notes.

5.2.4. Exit Interviews

I met the participants for the exit interview immediately outside the exhibition. At this point, they had been able to experience the remaining exhibition on their own. The duration of the exit interview depended the participants’ willingness to talk; I initially had five questions in my semi-structured interview guide:

1. What did you think?
2. What was experience of being in the exhibition?
3. What did you think about the story of the exhibition? (i.e. the key message)
4. Did you feel it was aimed at you?
5. Why did you come the the Planetarium today?
6. Demographic question, if not asked earlier, such as age and occupation (scientific or not a scientific background)

The order and emphasis of these questions varied according to what the participants found it relevant to talk about; I allowed them to talk freely about their experience. Often, they would discuss the questions without being prompted. At the end of each interview I would give them my card as well as a ‘goodie bag’ from the Planetarium.

Not all walk-alongs were successful. Some of them were cut short, for instance when the families coincidentally met some friends at the exhibit. In such cases, we stopped the walk-along to allow the families to interact with their friends.

5.2.5. Participants

The study included 14 walk-alongs, and the respective exit interviews, with 42 participants, of which 9 were female adults, 11 were male adults, 11 were girls and 10 were boys. Participants were recruited based on the target group formulated by the Planetarium in the early stage of the development of the exhibition, namely families with children around the age of 12. Therefore, I attempted to recruit all groups that consisted of at least one parent/adult and one child who I judged to be around 9-14, and that entered the exhibition together. The composition of the groups varied, including adult friends visiting with their children, and intergenerational groups, with grandparents and their grandchildren.

5.2.6. Data collection

Data collection from observations, walk-alongs, and exit interviews were collected during the Danish winter holiday (10-14th of February, 2020), as this is one of the busiest times for the Planetarium. Due to the holiday, the Planetarium had planned special activities that would not occur during a normal week. These activities included guided tours through the exhibition, an activity pamphlet (a word-hunt that took place in the exhibition), and activities in the Space Lab ('Build a Space Rocket'), as well as extra and special film screenings. Therefore, I had to plan the data collection around these activities so we were minimally disturbed by the guided tour, so the participants did not miss out on a planned activity or had to leave midway through the walk-along, and finally, so the participants were not influenced by having already seen a movie or participated in an activity. I therefore tried to recruit participants who had just entered the Planetarium. The audio recordings from the walk-alongs were transcribed on the same day as they were recorded, so that additional detail about families' interactions, movements and other details from the observational notes could be added with a high degree of fidelity.

5.2.6. Data analysis

The transcribed walk-alongs were analysed thematically (Braun et al., 2006) to identify and interpret the features in the data which pointed to the mediating processes as well as outcomes of the experience. The thematic analysis was conducted through six phases (Braun et al., 2006): familiarising, generating codes, constructing themes, revising themes, defining themes, and producing reports. The themes were divided into two levels, as I both looked for how the design conjectures embodied in the exhibition in general actually mediated and have an impact on the dialogues and if, how and in what ways the visitors physically and intellectually interact with the interactives. In the dialogue I looked for the type of conversation the families had on the science related topics. I coded for if the conversations were elaborate and included open-ended wh-questions, and explanatory comments on the understanding of the scientific concepts, leading to a joint meaning making, or if they were focused on giving directions and practical information's (such as 'push that button'), or finally if the conversations consisted of exclamations, such as 'wow, look!'. I

used a colour scheme to distinguish between meaning making dialogue, giving directions, and exclamations. I had not decided on these categories prior to analysing the transcriptions; they emerged as I read and reread them. The other level of what they talked about was coded in themes relating to the design conjectures. These themes were thus deductive, and included categories such as making link to own body, commenting on visual aspects. However, during the coding of the data, new themes arose, such as how the social context influenced the user experience, and I include these in my analysis as they proved important for understanding both the mediating processes and the outcomes.

5.3. Observed mediating processes of the design conjectures and their outcomes

Using data from the field observations, the walk-alongs, and exit-interviews I wanted to identify to what extent the design conjectures ([P4]) prompted the intended mediating processes and outcomes (Sandoval, 2014). The analysis of the mediating processes was based on the unobtrusive user group observation and the walk-alongs, while the analysis of the outcomes was based on the walk-alongs as well as the exit-interviews.

5.3.1. The 'Introduction': Creating connection and relevance

The intended mediating process were that the area A01a-c would serve as introduction to the key narrative and to provide the users with the basic knowledge needed to engage with the astrophysical themes in the central exhibition area. It therefore embody the conjecture that creating a connection between the users body and universe makes people want to engage with abstract knowledge.

There were clear patterns in how users approached the exhibit, from the perspective of both the field observations and the walk-alongs. As the users entered the darkened exhibition space, they were first drawn to the three screens with the words 'what are you made of?'. In general, the users would interact with the exhibit by dancing, moving and playing. In particular, the children would engage and the parents would act as mediators, reading the text on the screen and discussing it with the children. Sometimes, parents would take part by dancing and using their bodies. After interacting with the exhibit, the users would then continue to 'Building Blocks of Life' exhibit (A01c). They would read the texts and touch the objects, or be drawn into the central exhibition area without engaging with the exhibit.. The general user journey in the introduction is exemplified in the following example from Observation of group 7.

> *The family has entered and the girl (app.15) and boy (app. 12) are dancing, playing in front of A01b. The mother is reading the text on A01a, and the father watching the children play.*
>
> Boy: is that me?
>
> Girl: yes - look, you are made of stars!

The girl moves over to her brother and they are now playing together at the same screen. When the visualisation 'explodes' their silhouettes:

Boy: Wow, look!

Girl: 'we are made of the universe'.

The family walks over to 'Building Blocks of Life', they read the text, talk with each other, and touch the objects before continuing into central exhibition room. In this case, the exhibit 'Your cosmic history' with the Kinect interactive with 'exploding' images of human prompted the users to use their bodies. The older girl helped her younger brother to read the text, and she helped make meaning of the contents.

In summary, from the observations of the specific families, I found that the embodiment of the design conjecture in the physical design of the 'Introduction' area did prompt the mediating actions we intended. As intended, several people were able engage simultaneously, and generally, they would use their bodies in the interaction, dancing, playing, laughing, but also discussing, exclaiming and talking with each other about the text and their experiences. Many users would actively engage with the area with 'Building Blocks of Life' (A01c), where they could read about and touch examples of the different elements, as well as reading about atoms. Even so, it is not clear from the experience maps based on the field observations to which degree the design prompted the intended outcomes, nor to what extent the users were reflective and made meaning of the 'Introduction'. In the walk-alongs, however, I was able to ask more in-depth questions.

The first question I address is: To what extent does the mediating process have the intended effect of prompting outcomes, and what is the nature of those outcomes? In the excerpt below, I followed a family of four, Woman 5 (not with a natural science background background), Man 5 (with a natural science background) and their two children Girl 5 (aged 10) and Boy 5 (aged 7). The excerpt shows how interactions in some cases followed the intended mediating process as well as the outcomes:

The family is a bit shy in the beginning then starts to play with interactive at area 01B

Man 5: It hydrogen is from big bang [read out loud to son who plays, makes fight moves in front of Kinect].

Man 5 continues to read out loud.

Woman 5: you turned all red

Boy 5: What! [in English] that is really cool!

Man 5: Zinc from supernovas. It is all something that is inside of you [son's name], all these things

Boy 5: what! okay..

Researcher: what do you think of that story that it is all inside you?

Woman 5: I think it is pretty cool.

Man 5: it is thought-provoking, it is not something you think about every day.

Here, the farther (Man 5) mediates the meaning of the interactive to his son as they actively engage with the exhibit. Judging by the boy's exclamations, he seems to find the information interesting. The mother (Woman 5) does in this example not engage in the scientific knowledge, or tries the interactive herself, but is still part of the conversation. While Girl 5 also interacts and plays with the exhibit, Man 5 seems more focused on mediating the knowledge to Boy 5. The family moves over to 'Building Blocks of Life' (A01c), where the elements are linked to the human body, and where they are able to touch samples of the elements (in the form of rocks and a steel tube).

Man 5 reads aloud the text on iron

Boy 5: we saw that thing about health, and they said that that there were some families that lacked a lot of iron.

Woman 5: that's right, it's the program that we saw

Man 5: they had a low blood percentage

Woman 5: that is right, it has something to do with the blood, that's right. They were vegan right? And not having enough iron was dangerous

Man 5: it is written there 'the iron in our blood is the reason why it is red'[reads the entire text out loud]

He reads out the text on carbon, that it is in our and the Woman 5 says ' maybe you should explain what DNA is'

Here, Boy 5 and Woman 5 connect the knowledge presented in the exhibit with their prior knowledge from a tv-programme. In their dialogue, they generate meaning based on the exhibits. At this point in the exhibition, they have already made the connection between themselves and the universe, and from the exclamations of Boy 5, this connection is interesting to them. Still, the farther again takes the active role of mediating the scientific knowledge, and the mother further establishes his position as the knowledgeable person by asking him to explain what DNA is to Boy 5 and Girl 5.

In the exit-interview I asked the family of four to reflect on the story of the exhibition, without explicating that I meant the connection between universe and their body:

Woman 5: I think it is pretty good that there is the link to humans and the body - I think it is really good that you get that extra connection. […] It makes is more relevant - one thing is what has happened, and that you get a historical

perspective, but that you also can see, that it has an effect on how …

Man 5: [interrupts] that you yourself are linked to the universe, right?

Woman 5: And the elements that is there - even though it is also sometimes difficult to understand, but I thought it was interesting

This example shows that the mediating process happened as intended, and that even though Woman 5 does not see herself as a scientific person, pointing out that her husband is the knowledgeable one, she was able to verbalise the key message. Even though she did not explicitly take part in the interaction by using her own body, she still reflected on how she found the link to the human body interesting, and that it made the knowledge more relevant.

Another example of how the mediating process occurred as intended is in the case of Girl 8 (a 15-year old, who in her own words 'always [has] found physics boring', and her grandmother, Woman 8. Girl 8 had entered the Planetarium unintentionally, in that they had not planned to visit and had no pre-conceptions of what the Planetarium was. They merely entered the Planetarium because the forecast predicted rain, and they therefore changed their plans of visiting the botanical garden. However, they quickly became engaged and interacted very actively with the exhibits and each other. Prior to the exchange shown in the following, they had entered Made in Space and immediately engaged with the Kinect. Woman 8, exclaimed 'oh boy!' and Girl 8 'I'm made of hydrogen, what are you made of?'. Then, they moved over to area with physical representation of the elements and what their role in the human body are (A01c) and their interaction with the exhibit sparked this exchange:

Woman 8: […]It says ' you are built out of many different elements'.

Girl 8: 'many if them do somethings special to the body, here we have selected five of the most important'

Woman 8: then you can look at the colours,

Girl 8: of course iron

Woman 8: yes, and oxygen [struggles with the pronunciation]- oxy

Girl 8: oxygen. Carbon

Woman 8: zinc, zinc. And hydrogen. Wow - and there you can read what

Girl 8: yes, what does it say

Woman 8: iron is in your blood , that the reason you blood is red

Girl 8: oh yes, of course

Woman 8: [to Girl 8]molecules, is that also elements?

Girl 8: Yes, yes.

Woman 8: ‘when different atoms come together they form molecules’ - okay, molecules.

Girl 8: molecules

The intended outcome at this exhibit was that the users would be prepared to further explore the rest of the exhibition. In this case, Girl 8 and Woman 8 together create meaning about what elements and molecules are and what role they play in their bodies. At this point I probed a bit, asking them: ‘What you are experiencing right now?’:

Girl 8: it is really cool that you find out what there is in your body - I hadn’t thought about that.

Researcher: what is cool about it?

Girl 8: it is just that then you know what you are made of and where it comes from.

Woman 8: She has apparently had something about it in school

Girl 8: Yes, but I haven’t thought about - I new that iron was in humans, but I hadn’t thought about it in that way. And the experience, it is nice and [“rummeligt” which can be translated to both spacious and inclusive]

Woman 8: and it is a good way to look at it

Here, Girl 8 begins to see knowledge about atoms in relation to herself, and she finds it ‘cool’. She enjoys the experience, finds it ‘nice and spacious/inclusive’, even though she in school does not enjoys physics or see herself as being knowledgeable in physics. In this case, the 'Introduction' makes Girl 8 and Woman 8 aware of the key story, they find the story to be interesting, and they consider the basic knowledge needed about atoms and molecules to further understand the next part of the exhibition. Thereby the embodied design conjecture did in this case both lead to the intended mediating processes as well as the desired outcomes.

The following is an example of where the physical design prompted a process that was not intended. In this example, Woman 6 was visiting the exhibition with her 8-year old daughter (Girl 6). They had been through the exhibition while waiting for the film to begin, and had then re-entered Made in Space after having seen the film. Woman 6 did not have a scientific background, and she and her daughter had decided to visit the Planetarium after an experience they had shared waiting for a bus after nightfall, when they had been looking up at the stars and wanted to know more about the constellations. In the walk-along, while they were at the 'Introduction', Woman 6 remembered the previous exhibition at the Planetarium. As she compared it to Made in Space, she recalled how the previous exhibition was based on observation rather than interaction. She said:

> Woman 6: Here, you express [udfolde] yourself and see the different things can come around your body when you stand here, right? I think this is very cosy. [Addresses her daughter] You were outside the screen, honey. [the daughter dances in front of Kinect while we are talking]. Also, just that you, in there [points to central exhibition area], can see the sun, and how everything, and really spell it out. I think is it interesting, but I really wish that there was more about the night sky, that you could see the night sky, because that is what we thought when we came in here today, the reason why we came. But she is having a good time, and she is having fun, and it is the winter holiday, so as long as she is having fun, then we are just having fun and playing together

When Woman 6 discusses how the new exhibition is better because it allows the visitor to express themselves, uses the word body to talk about the experience, and expresses how having fun and playing together is important, she is describing the intended mediating process. Even so, when I asked her what she thought about the story, her answer reflected both her visit to the exhibition prior to the film and what she was seeing and experiencing while we talked:

> Woman 6: It means that you think - wow - is there so much dust around you, there is so many things that are around you. I think that that is a bit - wow - that it all just gathers around you form out there, right?
> *She turns her attention back to her daughter, who is dancing in front of A01b*

I want to point to how many times she uses the pronoun 'you', and how she sets herself in the centre of the story. In describing the story of the exhibition, her attention is on how the 'dust' and 'things' influence her. Her use of descriptive words rather than the scientific words used in the exhibit (e.g. atoms, elements or even metaphors such as building blocks), indicates that she perhaps struggled with, or did not pay attention to the core scientific content. However, even though she did not use the scientific terms, and perhaps had misunderstood the connection between the 'dust' and humans, she reflected on the connection between how the 'things' from 'out there' gathered around her, thereby affecting her.

In the following, I present two very distinct reflections on the exhibition experiences from two women who did not have any prior interest in or knowledge about astrophysics or science in general. One is Girl 8, the 15-year old girl visiting with her grandmother, mentioned in the preceding. The other is Woman 11, who worked as a secretary, and visited with her husband and two sons. In this case, the husband and oldest son seem most interested in the topic. Woman 11 was clearly focused on engaging her sons, but did not interact with the Kinect herself. Instead, she directed her sons by saying things such as 'Try going over to the other one [addressing Boy 11b]'. Further, when I asked her what she thought of 'Ingredients of

Life'(A01a) and the exhibit text she had just read aloud, she again put her sons' experiences in focus, explaining that the ingredients would perhaps make sense to them. In the exit-interview, I asked about the experience:

Woman 11:	it is a big area that I don't know so much about - I did gain something, but I don't have so much knowledge of all that oxygen and that, so I think I just took it as an experience. It is not something that captivates me in the same way that it does [her husbands name (Man 11)].
	[…]
Woman 11:	It is something that speaks to me - I don't know if I will take if with me, but now I know, at least. And I gained a good experience. And they [referring to the Planetarium] tried to teach me something in an understandable way.
Researcher:	do you think they succeeded?
Woman 11:	yes - but if you ask me in a year's time, I might not remember. But that has to do with interests, right? My interests lie somewhere else
Researcher:	and this hasn't changed the way you..
Woman 11:	No, because it is so far away from my everyday life, so it is not something I think about, but is it interesting to come here and learn it in this way.

For Woman 11, the outcome of understanding the key message that was embodied in the design and prompted by the mediating processes, was not something she would retain, as it was far from her everyday life even though it captivated her in the moment. In this case, the intended outcome of making the exhibition content relevant by connecting it her everyday life, and for her to see the herself in a new way, was not realised.

However, in the case of Girl 8, her reflections in the exit-interview over the key message show that the experience affected her:

Girl 8:	I actually think [name of younger brother] would find it interesting, really, he would read and
Woman 8:	He is very - kind of - science and
Girl 8:	yes, yes, it is a bit in opposition to his sister (Woman 8 laugh)
Researcher:	but did this change your view on -

Girl 8:	Very much. It has completely changed my view on it [her voice is happy]. Now I would want to talk to him about it, and be like 'Do you know what, [younger brother] we actually come from the stars, did you know that?'. I also think the reason I wasn't so interested was that I didn't know so much about it - then I just thought ' okay, it is a bit geeky, it is not really me'. But it is actually not so geeky at all, not geeky enough for me not to like it
Woman 8:	No, I can easily imagine why some people choose to do the science and all that

In this case Girl 8 again initially placed herself in opposition to her younger brother, and to being interested in science. In spite of how I observed her engaging with the content throughout the exhibition, she said things like 'normally in school, I think that physics can be quite boring, but here it's okay...' and 'you don't hear so much about it - not in school. We haven't heard about this reverse Big Bang. I have to ask my physics teacher about that'. The outcome of the experience was thus that her interest was sparked towards engaging in a field that she had not found interesting, or considered herself to be good at, prior to the visit. Therefore, in this case the intended outcome of motivating the users to explore by providing the necessary knowledge to do so, and for the users to view themselves in a new way, were realised.

I want to point out at this stage that the examples presented above, in some form or another, all shows how the intended mediating processes were very often prompted as intended, and that the outcomes were often realised as we hoped. I am cautious, however, in interpreting this as an indication of absolute success. The cases described in the preceding represent the most successful walk-alongs, in which the participants were highly aware of my presence and therefore perhaps more conscious of their actions than normally. In other cases, as in Walk-along A9, the participants were so shy and affected by my presence that they were unwilling to talk or engage, and remained in the exhibit for very few minutes. In these cases, where I felt that my presence clearly made them uncomfortable, I stayed in the background and did not pressure them to talk with each other or with me. Therefore, as they did not speak, I do not have recordings of their dialogue. In the case of WA9, I observed the users reentering and spending time in the exhibition afterwards, but I did not approach them further. I simply observed from a distance how they now engaged, played and talked with one another.

With the above examples I have shown how embodied design conjectures promoted the intended mediating process, and how the mediating processes, e.g. in example walk-along 8 showed how these led to the desired outcomes.

5.3.2. 'Small and Medium Sized Stars': The shared experience and social interaction promote meaningful dialogue

In the case of the exhibit *'Small and Medium Sized Stars'* (A07), I will show how the mediating processes shaped the social experience and it how did, or did not, lead to a meaningful and elaborate dialogue, and what the outcomes were. I found that two aspects were, perhaps unsurprisingly, related. The mode of interaction with the exhibition was strongly linked to the type of dialogue that occurred, which was strongly influenced by the social context in which the visitors entered the exhibition. This section will also briefly touch on the implications of gender.

In the observations of the specific families, I found that the plinth had, as many other exhibits, a offered a range of different interactions along the three continuums shown in figure 20.

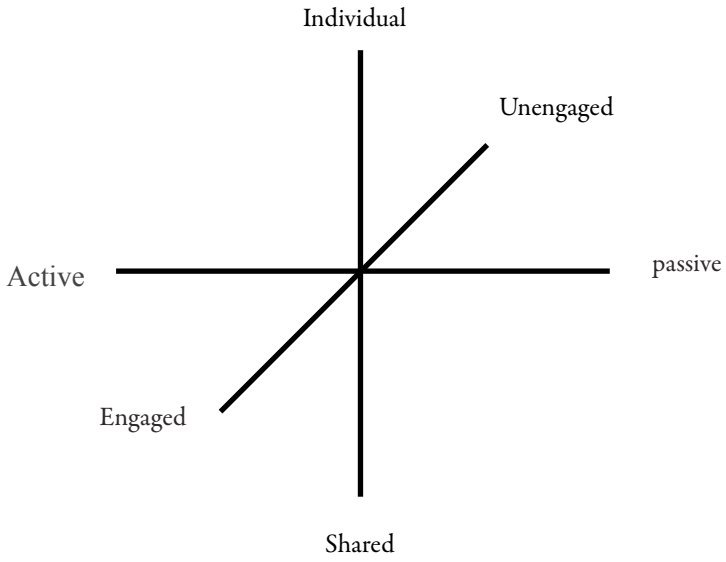


Figure 20: *Active*: uses body, interacting with interactive (playful, dancing, running, exclaiming), pushing buttons. *Passive:* standing more still, calmer movements. *Engaged*: Reading, talking, discussing, testing.*Unengaged:* Not spending time at exhibits, not reading, talking, discussion. *Individual:* mostly interacting alone. *Shared:* mostly interacting in collaboration

Hence, it is possible for a family to be highly active and have a shared experience, while remaining unengaged in the scientific content. A group is not necessarily collectively located in one part of the diagram; different group members can be located in different part of the diagram at different times. An example of how interaction continuums played out is given in my observation notes regarding a specific family: a girl (app. age 14), a boy (app. age 9), and what I assume is their mother and grandmother (Woman and Woman(older)). At the time of the observation, they were alone in the exhibition, while a film was being shown.

> They disperse again, walking over to other interactive station (haven't noted which ones), they are alone in the exhibition still, so they walk over, standing by themselves, mostly B+G(older) who does not talk, but more interacts with interactive, testing them, not standing at one place for long.
>
> G + W stand together, talking, exploring together, then sitting down and watching the full supernova film (A10). B is back on A06 with W(older), W+G walks to the back wall, then all exit through the Afterword.

The interactions described in the preceding example show how people disperse and meet at the interactive stations in front of the projected screen, and how they interact in different modes at different times. In this case, W and G were both active and engaged, reading, talking and discussing the exhibits. Boy and Woman (older) on the other hand were active but did not engaged with the scientific content of the exhibition. Even though I did not have access to their conversation, I noted that G and Woman talked and pointed while B and G (older) did not talk or spend long periods of time at any one exhibit. However, at times B interacted with his sister, seemingly having a shared and engaged interaction.

During the walk-alongs, I discovered how the roles of the family members implicitly and explicitly became the focus when the users spoke to me, for instance in walk-along 11 where both Man 11 and Woman 11 stated several times how B11a (the older brother) was interested in the content, but B11b (the younger brother) was not. This relationship is also reflected in their interactions, where the younger brother mainly interacted with his mother. In contrast, Man 11 and the older brother were engaged in talking and pointing. The younger brother was was not allowed to take meaningful part in the collaboration. In this case, the father interacted with the interested child, while the mother became the caretaker of the less interested child.

I found a similar example in walk-along 13 where Boy 13 (younger brother) goofs around, but at the same time monopolises interactive station. His older sister (Girl13) seems to want to have a meaningful interaction, but is hindered by her younger brother. In an example from another family, I found the same pattern, where the older sister in the family (Girl 5) interaction with the interactive station, but her father (Man 5) and her younger brother (Boy 5) did not allow her to also influence the interactive. At the same time, Man 5 only addressed Boy 5 in spite of Girl 5 clearly showing interest. In these social interactions the girls are hindered in their interactions, not by the design or the physical space, but though the social (and cultural) context in which they entered. In these examples it is clear that the social context strongly affects the mediating processes, and thereby the outcome.

However, as I will discuss in the following, other more positive interactions also took place during the walk-alongs. I remind the reader that my presence did interfere with the users' experience, which may have

led them to engage more intensely, and for longer periods of time, than they would otherwise have done. In some instances, I even invited the users to approach 'Small and Medium Sized Stars' interactive if the exhibition space was busy and the interactive station was available, thereby interfering with their journey. This sometimes lead to the participants to spend longer time in front of the station, as exemplified in Walk-Along 8, where Girl 8 at one point becomes annoyed with the interactive on the touchscreen,

Girl 8:	I'm just really eager, and then I can't make it work - I would just continue on
Researcher:	Would you have done that now?
Girl 8:	Yes, I would.

Still, the walk-alongs allowed me to record and note how people acted and talked in front of the interactive stations.

First, an example of the family from Walk-along 6, a mother (no scientific background) and her daughter, who I presented earlier, where the conversation mainly consisted of giving directions and making exclamations. I also observed making meaning dialogue; however, this dialogue was based on references to popular culture and prior knowledge rather than the scientific content on display:

In the beginning it is quite evident that Woman 6 doesn't really know what to do

Woman 6:	look, now it is lit, that one, right, honey?
Girl 6:	Wow!
Woman 6:	It is pretty cool to see it this way, right? Now you are just back - I think you have to go a bit higher on the circle there - then it just opened up, then. We haven't seen that before. It is quite cool to see how it can… Oy, look at how much it really
Girl 6 :	Oh, try to look, the small one.
Woman 6:	That's the thing - that you can zoom in and she how it looks inside. A bit like if you open a human body… 'The core of the star' - can you do that? Perhaps first when you go a bit further - Look!
Girl 6:	uuuuh…
Woman 6:	then the core came out there, right? Can you see that honey? And then when click here it comes further and further out.

Girls wants to touch something else

Girl 6:	Wait, I …
Woman 6:	We are just doing something else right now, right. Don't… It looks like a gobstopper [forvandlingkugle] when it is out, right?
Girl 6:	NOW we have to catch them all [Pokemon reference]
Woman 6:	yes, you have them all on now. And it is a bit cool to see how it is. ..
	…
Woman 6.	It actually looks like and orange, and a melon, where you have taken the seeds out of the melon, and put it on the side, if you can call it that, right?
Woman 6:	Look, now it is burning [nu er der ild i den]. It is (laughing) - it is pretty wild to see that you can do it in this way, really get in depth with the things, right? Look at it now!
Girl 6:	Wauw, it is beautiful!
Woman 6:	then it is just completely out—- I think it is an amazing thing to come and experience something, and see what you can do, and touch the things, and try it out, and then it is a good playground for her, then she can try something new, right.

As mentioned, this conversation is mostly giving directions, for instance when Woman 6 says 'Now you are just back - I think you have to go a bit higher on the circle there - then it just opened up, then.' She is giving her daughter directions and describing what she sees on the screen. In this case, the pair do not relate it the scientific content. However, they do use words such as 'core', and interact and relate the contents to their prior knowledge, e.g. talking about how it looks like a gobstopper, an orange and relating it to Pokemon.

This next example shows a quite typical interaction, where the family in Walk-along 2 stand together around the interactive station, and points, works together, and discusses the scientific content:

Woman 2:	the sun right now. That is the sun. Does it get bigger?
Boy 2:	yes gets bigger as more time passes and then it becomes a…
Man 2:	see, now we are where the sun is right now
Woman 2:	oh, okay, the sun right now. It is the little one there
Man 2:	Then it gets bigger - try to look up there.
Boy 2:	and then it gets bigger
Man 2:	[interrupts] see if we can see how old it is. Then it gets older and older and grows bigger and bigger
Boy 2:	and then it gets warmer…

Woman 2: And then it gets warmer on earth too

Man 2 : yes

Woman 2: but that doesn't happen in our life [we laugh]

Man 2: look, it gets as big as – all the way out to earth

Boy 2: and then it becomes smaller

Woman 2: Try that again

Man 2: right now it is there

Woman 2: yes… ah, and then it fits with… doesn't it? [The small sun in the upper left corner for size]

Man 2: It doesn't.. it becomes really big [the sun becomes suddenly really big] Wooow

Woman 2: oh, no, no, no … when does it say that will happen?

Boy 2: now it becomes comes again a… or – it will explode

Woman 2: Will it explode in the end?

Boy 2: Yes, it explodes!

In this case, the family interacts. All three members of the family are working together and taking part in the dialogue, elaborating on what they see and asking each other questions about the content which they then find the answers to in collaboration. Embedded in their talk is their meaning making of how the star gets 'older' and 'warmer' and that it will 'explode' in the end, which in essence is the life cycle of the star. In this example the interactive station works as a station for collaboration, and all parties are equally engaged in the conversation, and where the parent-child conversation leads to meaning making.

In another case, however, the interactive station reinforces already established social structures, as mentioned above and exemplified in the following. In this case Girl 5 wants to interact, but is hindered by her brother:

Boy 5 runs over to small stars A07, and I follow them.
*Girl 5 and Woman 5 is still at A0*4.

Man 5: this is a star's life. Now it is young, 0-9000 years. 7,8 mill decrease at the core [again, he reads out loud to son].

Woman 5 and Girl 5 joins us, talk in the background. Girl 5 tries to interact with the touch screen

Boy 5: [takes over] No, no, we do it like this…

Man 5: if you move it a bit forward, does it then change? [to Boy 5] it does, right

Boy 5 : [exited] now it is a million…!

Man 5: the core temperature drops a bit - can you see that - [to son] and then it rises again

Boy 5: what if we move it to the top?

Woman 5: See how many million degrees!

Boy 5: Wow!!

Man 5 [reads out loud]: the star grows and throws the outer layer…… it then turns into a white dwarf - can you see that it turns white?.

Boy 5 and Girl 5: yes

Man 5: [reads out loud]'this is how our sun will end its days, many billion years from now' - it is crazy, huh?

Boy 5: yeah!

Man 5: Look the sun is here. This is how the sun is right now [Girl 5 begins to say something but is interrupted]

Man 5 and Woman 5 explains Boy 5 about diameters.

In this case the Man 5 (who has a background in science) takes on the role as teacher for his son; however, it is more difficult for Girl 5 to be part of the collaboration. During their interaction with the interactive station I ask them what they think of the experience. Girl 5 answers that she thinks it is pretty cool, and Man 5 elaborates

Man 5: it is strange to think that what we are made of comes from the stars - have you thought about that before?

Girl 5 and Boy 5: no!

Woman 5: and also, the thing that - that our sun it evolves, right? I think that is really interesting [the other agrees in the background].

This example illustrates that even though the social context did perhaps in some aspect constrain the collaboration, the interaction still gave rise to meaning-making between the family members. In the quote Man 5 and Woman 5 acts as facilitators and verbalise the intended learning outcome, something Girl 5 returns to in the exit-interview:

Man 5: Hm… I don't know if it makes it easier. I think it is more that you find out that you are part of (Girl 5 interrupts: that you are made of stars and space), yes exactly, but I don't know if it makes it easier to understand per say - it is just that experience - that 'aha' experience that you get

Girl 5: That you know that you are made of stars

In other words, in this quote Girl 5 shows both excitement and a desire to participate in talking about what they have learnt in the exhibition. She is able to verbalise the general key message, but does not include e.g. the atoms names.

This next family group exemplifies how the experience can lead to the mediating processes as well as the intended outcomes. For Girl 8 and Woman 8 the screen to interactive station connection and the technical aspects of the setup causes some problems, however the mediating processes and resulting outcomes are quite explicit in this example:

Girl 8:	SO we are stars? You can call me nova from now on [we laugh]
Researcher:	what is it that's difficult?
Girl 8:	It is just - it is so incomprehensible- it is so far away. How can it come down to us? How can I be part of it?
Woman 8:	It is so many years ago…
Girl 8:	is that a spelling error?
Woman 8:	'It is stars that are 8 times heavier than our own star, the sun
Girl 8:	does that make sense?
Woman 8:	yes, our own elements in our bodies comes from large stars - but that makes wonder, I mean, we descend from the apes,
Girl 8:	do they also originate from the stars?
Woman 8:	They must
Girl 8:	that's it!
Woman 8:	you really have to go back… [directing her on the screen, that she has to scroll a bit backwards]
Girl 8:	I actually understand it now: Big Bang start, and then the - I just didn't know it was stars, I thought it was small bacteria that then became apes which then became humans
Woman 8:	yes, which gave life on earth … I think it is - I think it is a bit difficult to understand - but interesting
Girl 8:	But it makes more sense than if God created us.
Woman 8:	It is easy to understand that some people are crazy about these things
Girl 8:	Yes, I can understand that too now - I said to my grandmother when we entered 'I can't be bothered…To look at stars, grandma, I can't be bothered'. I thought it would be boring
Researcher:	so, what do you think now?

Girl 8: I think it is nice that we have learned something. I also think it is interesting.

In the case of Girl 8 and Woman 8, their experience in the exhibition in general, but also at the interactive station is an example of how the two make meaning together through an elaborate conversation, asking each other questions and searching for the answers in the text through the interaction. Here, the mediating process of providing room for collaboration and shared experience occurred as intended. What is more, at this moment and in this context, the intended outcome was achieved in that these visitors came to view themselves and their origins in a new way.

In summary, the interactive station embodied the design conjecture successfully by allowing for, and often prompting, the mediating processes of shared and collaborative experiences. These collaborative interactions gave rise to dialogue and elaborated conversations, where *wh*-questions and open-ended questions occurred, and where joint meaning making took place. Even though the social (and cultural) context, including previously established social structures in the group, conditioned this meaning making, the exhibit design and content promoted dialogue and meaning making. This led to users gaining an understanding difficult scientific content regarding the life cycle of a star.

5.4. Discussion

In this chapter I wanted to answer the question: How are the conjectures of the various exhibition developers, regarding astrophysics, astronomy, and the visitor experience, embodied in the exhibition and enacted by users of the exhibition? Specifically: how are the gender inclusion aspects of the exhibition realised in the user experience, and what are the implications of this realisation for the design of inclusive exhibitions?

5.4.1. How are the conjectures embodied in the exhibition enacted by users of the exhibition?

To answer the first part of the research question, I argue based on the preceding analysis that the embodiment of two design conjectures were successful in prompting the intended mediating processes, leading to the intended outcomes. These two design conjectures were:

> Conjecture 1: Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge

Design conjecture 2: creating shared experiences allows for collaborative interaction and the social construction of knowledge

With respect to the first conjecture, the analysis showed that the introduction exhibit 'Introduction' lead to playful, bodily and shared interaction, where people did not hesitate to engage with complex knowledge, and where they related the content to themselves, their bodies, and their prior knowledge and understandings of themselves and their origin. In some cases, the users did not did not actively reflect on story presented in the introduction while engaging with the remaining exhibition, and it was understood as something separate. However, in the exit interviews the users did reflect on the story of being made in space, and they responded positively to both the experience of being in the exhibition room as well as the story.

With regard to the second conjecture, the meditating processes also were prompted as intended. Indeed, the interactive station did lead to dialogue, it did lead to several people engaging at the same time and it did lead to meaning making. Further, in most cases the learning outcome was achieved. However, as laid out in the preceding, and discussed below, both the 'Introduction' as well and 'Small and medium sized stars' also inadvertently reproduced unintended gendered performances.

5.4.2. How are the gender inclusion aspects of the exhibition realised in the visitor experience?

Even though the mediating processes occurred as intended, I also found that previously established patterns on how girls/boys, women/men act in exhibitions (cf., Archer et al., 2016a; Dawsson et al., 2020; Silvfer, 2019). Further, the parent-child discussions did in some cases mirror that of previously established gendered norms (cf. Crowley et al., 2001; Tenenbaun & Leaper, 2003).

Meaning making and the social context

In regards to meaning making through conversations and dialogues within the families, there are two things at stake: one is that the parents engaged more actively with those children who had a prior interest in astrophysics, the other is that parents were more likely to explain to sons than to daughters. First, having an identity as a 'science person' affected how adults and children engaged with the exhibits. This manifested itself in the way parents talked differently to their children based on the parents' perceptions of their children's prior interests; this difference was subsequently reflected in the children's behaviour. This finding is in line with previous studies, which show how parents (mainly fathers) are more likely to engage with the 'expert' than the 'novice' (Palmquist & Crowley, 2007). Thus, in some cases, Made in Space seemed to reinforce pre-established notions of which family members are 'scientific', thereby potentially influencing the development of the science identities of the children (Calabrese Barton & Tan, 2010, Carlone, 2004).

Second, there was a tendency for the 'science persons' of the group to be either the fathers or the sons. In accordance with former studies, the fathers were more likely to engage in scientific reasoning with their sons than their daughters, which has previously been found in both home settings (Tenenbaun & Leaper, 2003), and in science exhibitions (Crowley et al., 2001). This is important because the explanations and meaning making curated by the parents in informal science leaning environments may influence the scientific literacy of the children (Callanan & Oakes, 1992; Crowley et al, 2001; Haden, 2010). Thus, the social context in which the family enters strongly influences their visit, experience and consequently meaning making. This is perhaps not a new revelation, as it is well established that the sociocultural context is an important contributing factor to the museum visit (e.g. Davidsson & Jakobsson, 2012; Falk & Dierking, 2000).

Gendered interactions

In my data I saw how boys would 'goof around' and be loud and dominant e.g. by wanting to control the interactive features and not allowing their sisters to engage. In previous studies these behaviours have been linked to gender performances of stereotypical masculine norms (Archer et al., 2016a; Silvfer, 2019). Similarly, I found that the girls would act within gender stereotypical norm for femininity, in that they would first allow and accept this behaviour. Their interactions with the interactive exhibit were more subdued, and they tended to be more quiet (Dawson et al., 2020; Silvfer, 2019). However, even though the behavioural patterns in some cases followed the stereotypical norms for intelligible way of performing gender in a museum setting (Archer et al., 2016a; Dawson et al., 2020; Silvfer, 2019), I also found examples where these patterns were altered.

An example one such change is offered by the users' interactions in The Introduction exhibit. The analysis above showed that this part of the exhibition led to similar behaviour between the boys and girls, father and mothers alike, where the users interacted with the exhibit regardless of prior knowledge and/or interests. Further, in the talk between the members of the family in this area would, in general, allow for a common and joint meaning making. In the exit interviews, the users would, in most cases, reflect on the key story of the exhibition, and express that this had been a positive and interesting 'aha'-experience. This too was regardless of any prior attitude towards astronomy and astrophysics.

Based on the users feedback, the first impression of the exhibition were therefore that it was 'spacious/ inclusive'(Girl 8), fun, and a place where the family could interact together. Godec (2019) studied school visits at science museums, and found moments that provided another type of engagement with science. This other type of engagement expanded what was accepted as 'scientific' to include a broader range of resources and behaviours. In a similar way, Calabrese Barton et al. (2013) found how shifts in the nature of figured worlds (including norms, ways of engaging, intelligible ways of being a 'science person') worked as catalysts for changes in science identity, i.e. competence, performance, and recognition within field of

science (Carlone & Johnson, 2007). I argue that exhibit The Introduction represented an opportunity for one such moment, where the users were able to interact with astrophysics in a way that differed from the traditional portrayal of the discipline (e.g. Levin, 2010; Nicolaisen and Achiam, 2020), thus prompting a small shift in the figured world. Though small, this shift could point to how designing for more inclusive interactions with the exhibits can allow for a broader set of resources and behaviours to be accepted as intelligible ways of engaging with science.

This type of interaction did in some cases lead to a change in the users understanding of themselves. In the present study, the mothers and daughters often distanced themselves from being a 'science person' interested in astronomy and astrophysics. For instance, Woman 11 distanced herself, verbalising that it is her husband who 'understands these things'. In the exit interview, she stated how she 'doesn't know much', and that science is not something that captivates her the way it does her husband. Even though her experience in the exhibition led her to reflect on the connection between her body and space, and express interest in this during the exit interview, she maintained that it was not something that would transform her interest in science. A contrasting example is offered by Girl 8, who repeatedly pointed out that she found physics boring in school, and that her younger brother was the 'science person'. However, in her case there was a shift in how she viewed herself in relation to science. During the visit she was presented with new and alternative aspects of science that were meaningful and relevant to her reflection of herself and the world. Thus, by being presented with other ways of engaging and interacting with science, she was prompted to reflect over her own position as a science person, stating that she no longer finds it 'too geeky'. Here, I will argue that the change in how astrophysics was presented, and the interactions made available through the consistent link between the concrete (the body) and the abstract (the Universe) provided this shift.

To think about how the interactions made available to users through the interaction in a museum context can influence and impact their actions and thoughts is not by any mean a new notion (cf. Davidsson & Jakobsson, 2012). It is exactly in this interaction that the possibility for transforming and influencing the users' life, and it is in this aspect the museums holds power, and therefore responsibility (e.g. Black, 2012; Feinstein, 2017; Hein, 2011, 2010,).

5.4.3. What are the implications of this realisation for the design of inclusive exhibitions?

An important finding that can be derived from this study is how well-established gender structures are within our society, and how much the sociocultural context influences the visit. As we discuss in paper 2 (Nicolaisen & Achiam, 2020) on the implied visitor, exhibition designs cannot guarantee specific visitor interactions, but they can provide opportunities for visitors to choose interaction strategies that allow for a meaningful and fruitful experience. As previous research has found, museums are capable of changing their

visitors (Hooper-Greenhill, 2007; Newman, McLean, & Urquhart, 2005; Soren, 2009). Godec (2017) and Calabrese Barton et al. (2013) found young people's views on themselves in regards to science changed when a broader range of resources and behaviours in engagement with science were valued. Though the exhibition Made in space may not change what is constituted as intelligible ways of engaging with science in general, or astrophysics in particular, it is part of the matrix of experiences and lived life that shapes our understanding of the world (Rennie & Johnston, 2004). My argument is thus if we continue to create awareness of how these inequities exists (Archer et al. 2016a; Dawson, 2014a; Dawson et al., 2020; Feinstein, 2017), and how we can design exhibitions that value multiple aspects of science, we can begin to change the status quo.


PART 6

6. Connecting the dots and design guidelines

In Paper 2 [P2] discussed how the exhibition Space Mission at the Planetarium presented space exploration in ways that reinforced stereotypical views of space technology and astrophysics. In addition, the following Paper 3[P3] showed that the dominant discourses found in the research domains of astrophysics, space technology and planetary science manifested themselves in the way astrophysicists talked about, and selected, content to be presented in the exhibition Made in Space. It was not until we, in the exhibition design team, began to operationalise postmodern feminism in our ways of thinking about science that these dominant discourses were contested and changed. Finally, the collaborations with users described in Paper 4 [P4] generated and negotiated the ideas on how to design inclusive content and form that were included in the final design. Looking back at this progression of research and practice, I argue that our approach to creating inclusive exhibition design, in which we gave voice to the underserved by including them and collaborating with them throughout the design process, led to a more inclusive exhibition design. Thus, in the final chapter, I will provide suggestions for theoretical development and insights into how we can design exhibitions

6.1 Theory development

In design-based research, there are two types of end products: the final embodiment of the design process (in the present case, the Made in Space exhibition), and theoretical development which can act as a qualification of design procedures, problem analysis and design solutions. Edelson (2002) defines how theoretical insights can be generated based on design research. One common theoretical outcome of design-based research is a *Design Framework*. A design framework is a prescriptive, generalised design solution, for instance, what are the characteristics that the design of the exhibition must have in order to achieve the desired outcome of being more inclusive? The framework consists of a set of prescriptive, generalised design guidelines (Edelson 2002; Laherto, 2018). This type of theoretical insight typically describes how to design an element or object for a learning situation in order to reach the desired outcomes (Edelson, 2002).

6.2. Development of Design Guidelines based on Made in Space:

In this thesis I have worked with design conjectures as a means to explicate and track the design assumptions that characterised the design process, how they were qualified on the basis of user collaborations, and finally how users at the Planetarium acted and interacted in the finished exhibition. The final step is therefore now to generalise change these design conjectures to become design guidelines for future designs of inclusive exhibitions, as illustrated in figure 21.

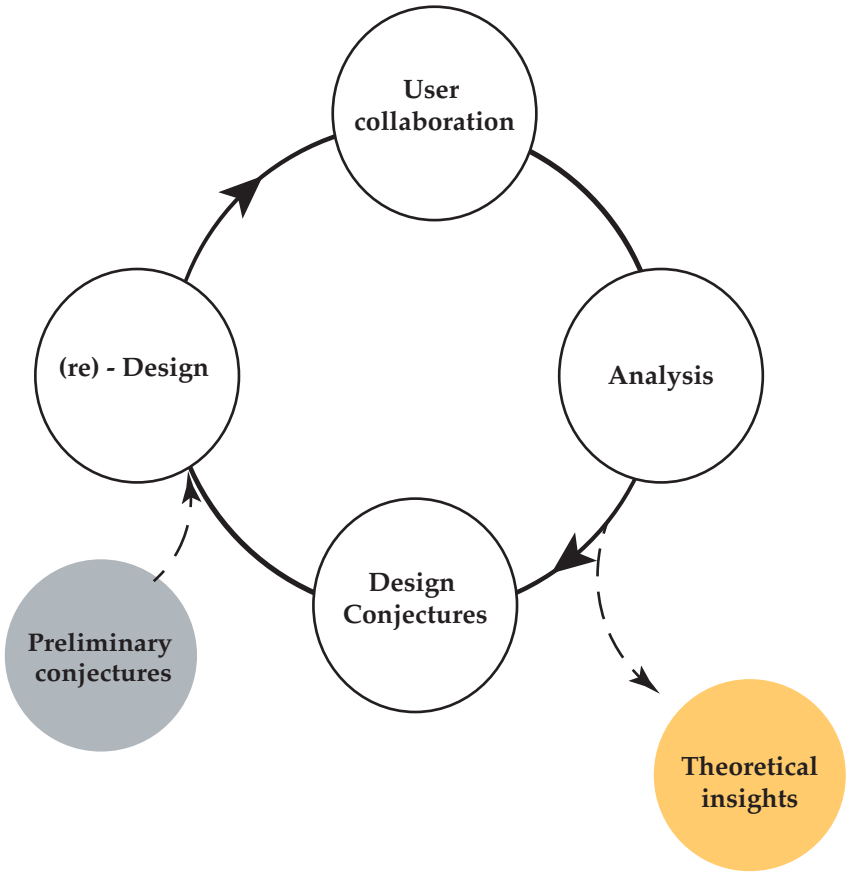


Figure 21: The design model used in this research, and the focus on the theoretical insights.

The design guidelines are:

1. **Linking or connecting a visitor's own body (the concrete) and the Universe (the abstract) enables them to, and makes them want to, engage with abstract knowledge**

2. **Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making**

3. **Providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways.**

These design guidelines should still not be understood as final, but rather as the somewhat tentative outcomes of this process and product; as such, they can and should lead to new experiments and testing. However, these three guidelines can provide direction to practitioners who wish to address the challenge of creating more inclusive exhibitions and thus a more equitable access to knowledge. However, they cannot stand alone; an inseparable part of creating more inclusive exhibitions is the process of how we develop them and, most importantly, who is included in the process.

1. Linking or connecting the concrete (e.g. the user's body) and the abstract (e.g. the Universe) enables the users to, and makes them want to, engage with abstract knowledge

When dealing with highly abstract and intangible knowledge, it is important to anchor this in the users' everyday experience, prior knowledge, and understanding of the world. This is perhaps especially important in out-of-school learning environments such as exhibitions, where the free-choice nature of the experience requires the topic to be relevant in order to capture the users' interest and engagement (Laherto, 2018). To anchor abstract knowledge to the concrete, however, also poses a challenge, as this link needs to be both meaningful and intuitive for the users to engage with without creating misconceptions. It is therefore important to both investigate and understand users' everyday experiences of a particular topic as well as test the idea for anchoring concrete and abstract ideas.

2. Creating shared experiences prompts debate and discussion on complex subjects, which enables joint meaning making

Creating a shared experience that promotes shared meaning making between family members, and users in general, are important aspects of how we gain, understand and conceptualise new knowledge (Miller, 1993, Falk and Dierking, 2000, Dierking, 2013). When designing shared learning spaces, it is therefore important to ensure that they do not prompt competition, and that different approaches to the content are valued and built into the design. These different approaches could focus on use of the body, such as dancing, playing, and physical skills, on reflective, emotional, and social connections, or on teamwork together as a family, group or community. However, as we saw, dialogue carries the risk of reproducing unwanted and inequitable patterns when talking science (Tenenbaun & Leaper, 2003, Crowley et al., 2001). Thus, this issue is perhaps the most important to address, and needs further research and development.

3. Providing room for open-ended questions in an immersive experience allows visitors to approach abstract knowledge in imaginative and emotional ways.

When designing inclusive experiences, it is key to promote a variety of trajectories into science, as well as allowing for different perspectives on science (Sinnes, 2006, Achiam and Holmegaard, 2015, 2017, Nicolaisen and Achiam, 2020). The design and setup should provide room for reflection and diverse views on the world and our place in it. The potential for transformation of these views lies in this imaginative and emotional approach, where the aesthetic experience can capture and inspire the deepest kind of personal meaning making (Bedford, 2016). The emotional, bodily and imaginative experience can create a new understanding of self and the surrounding world. Therefore, when designing new exhibitions based on operationalising of post-modern feminist ideas of equity, it is important to consider how to design an experience where the ‘wow’ is just as important as the ‘why’ (Hein, 2010). This can be achieved by creating immersive experiences in the physical space, focusing on allowing for open-ended questions and a strong focus on including other viewpoints and voices.


PART 7

7. Concluding remarks

I now return to my overreaching research question of, **how is the science of astrophysicists transformed to become the science of visitors in a planetarium setting, and what are the implications of this transformation for the inclusivity of planetarium visitors?**

I answer this question both from a retrospective and prospective point of view:
From the first paper [P1], we studied planetarium dissemination practice from the view of the practitioners, in this case Scandinavian planetarium education professionals. It informed the following research by establishing that planetarium professionals see enlightenment as linked to experience. The connection between cognitive and aesthetic factors, and the connection between 'why' as well as 'wow', has qualified how I in this thesis view the concepts of enlightenment and experience within planetarium practice.

The next paper, [P2], is the first to focus on the case institution and the project collaborator, the Planetarium in Copenhagen. We found that the dominant discourse within the exhibitions presents astrophysics ASTPS as technical and fact-based, and the visitors needed a high level of prior knowledge in order to engage with the content. The organisation of the activities focused on individual, competitive and game-like activities. We argue that these are symbolically associated with the masculine gender, and the gendering present within ASTPS were therefore also present within the planetarium exhibition. We further argue that these representations and organisation of ASTPS may hinder the inclusion of a diversity of visitors across the gender spectrum.

The retrospective part of the thesis showed that the science of the astrophysicist was transformed in a way that reproduced the masculine gendering found within the culture of astrophysics, and that the implications for the visitors were that those who do not fit comfortably within the narrow structure may feel excluded.

In the prospective part of the thesis, the aim was to challenge and change this problem by operationalising postmodern feminism through a design-based research process. In the third paper [P3], we turn the focus to the first part of design process of the new exhibition, Made in Space. Here, we show how the transformation of the ASTPS knowledge occurred before and after the user interventions and the focus on inclusion. This paper therefore addresses the first part of the research question above, and shows that the transformation of the science of the astrophysicists were at risk of reproducing the dominant discourses of ASTPS within the new exhibition. These discourses were disrupted through the focus on inclusion and the implementations of postmodern feminist perspectives, ultimately replacing the existing discourses with more inclusive ones. This paper therefore focuses on how the transformation of the science of the astrophysics are influenced by the inclusive perspectives.

In the fourth paper, [P4], the focus is on the operationalisation of the postmodern feminist perspectives in the design process. It describes how the design conjectures were initially formulated and reformulated, based on user collaboration, and therefore focuses on what the implications of postmodern focus are for the users. Based on this work, I formulate three general design conjectures, which have both a practical and a theoretical aim. The practical aim was to produce an inclusive exhibition, by the embodiment of these conjectures into the design. This work was acknowledged in June 2018, when 'Made in Space' was awarded the European Network of Science Centres and Museums' Mariano Gago Award in the 'Sustainable Success' category for being inclusive and engaging. The theoretical aim was to produce design conjectures, which I could then test in the final analytical part of the thesis, Chapter 5.

In chapter 5, I investigated what the implications of these transformations were for the diversity, or at least, for the inclusivity of the users of the planetarium. This led to the formulation of the theoretical implications to design frameworks in chapter 6. However, I found that even though the users in general interacted with the exhibits and each other as we intended, unintended reproductions of unwanted gendered patterns also occurred. These results therefore point to more research being needed to further experiment and test how we can design museum environments, where these patterns are replaced with more equitable ones.

7.1 Future research

My objective as I started this research project was primarily to provide a framework, which was rooted in theory but applicable to practise. This framework would create guidelines which could make exhibitions on astrophysics, and science in general, more inclusive to a more diverse user-group. As I write this, I'm confident that this thesis is a step towards that goal. However, it also points to the work that lie ahead, both within research and practice.

I see a future research effort in continuing to study and understand the role out-of-school science play in the formation of science capital and science identity. A key to success in this effort lies with the museums themselves and their willingness to create sustainable changes within their practice. Therefore, to further investigate how we can design exhibitions that provide a more democratic and inclusive access to knowledge, I advocate for the potential of the design-based research framework, which implement theoretical insights, but at the same time is, and should continue to be, anchored in practice.

Final Perspective

I read The Little Prince by Antoine de Saint-Exupéry for my daughter as a bedtime story, and in it the author make the tacit things tangible. For examples, as he describes the planet the the little prince live on (Astroid B612), he explains that the Turkish astronomer, who discovered the astroid, was not taken seriously the first time he presented the new astroid to the astrophysical community at at conference in 1905. He was wearing what in their eyes where 'funny clothes', he was something 'other' and his words rendered unworthy. First when he, in 1920, showed up dressed in a smart suit, he was taken seriously - though his presentation was the same. This is of course a very simplified description of what is intelligible ways of preforming 'astrophysics', but in its simplicity it is also strikingly accurate. In this thesis the argument has never been 'we need to change the visitors', rather the argument is 'we need to change the environment, the culture'.

Other Publications, Conference Contributions and Popular Science Communication

Non peer-reviewed journal articles

Nicolaisen, L. & T. Ibsen (2018). Made in space: At designe for inklusion i en udstilling om astrofysik, MiD Magasin, 39, 26-30.

Peer-reviewed conference contributions

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Nicolaisen, L. (2019), Præsentation ved symposium: Scientist talk: Conjectures of the implied visitor. Conference of ESERA (European Science Education Research Association), Bologna, Italy, 28.8.

Non peer-reviewed conference contributions

Nicolaisen, L. (2019). Hvor og hvornår gør forskningstilknytning en forskel i udstillingsudvikling? INDsigt seminar, Institut for Naturvidenskabens Didaktik, Københavns Universitet, 11.6.

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