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PhD Thesis

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Sustainability in Out-of-School Science Education: Moving Towards the Future

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"The more clearly we focus our attention on the wonders and realities of the universe about us, the less taste we shall have for destruction"

— **Rachel Carson**

“Why is English so widespread today, and not Danish?”
— **Yuval Noah Harari**

Popular Abstract

We are all becoming familiar with the term ‘sustainability' and are aware that education plays a major role in moving towards a greener future. However, what does sustainability actually look like in science education in out-of-school settings, such as museums, science centres, zoos, aquaria and planetariums? The fuzziness and complexity of sustainability often challenges their educational efforts, and so in response I give concrete suggestions from a perspective of research, policy and practice. Denmark is a country often applauded for progress towards sustainability, providing a strong platform for researching education practice in out-of-school settings. Firstly, I operationalise sustainability in ways meaningful to the specific educational missions of these institutions, and next map the landscape of sustainability education across Denmark. Finally, I select strong candidates for effective sustainability education, to develop guidelines for out-of-school settings. I hope that the guidelines can support out-of-school settings in the difficult process of operationalising sustainability for their education practice. Ultimately, the project qualifies the practices of out-of-school settings in their endeavours to prepare us all for a sustainable future.

Popular Abstract in Danish

Begrebet 'bæredygtighed' er efterhånden velkendt, og vi er alle klar over at undervisning og formidling spiller en vigtig rolle i den grønne omstilling. Men hvordan ser bæredygtighed ud i den undervisning og formidling der finder sted i eksterne læringsmiljøer så som museer, science centre, zoologiske haver, akvarier og planetarier? Fordi begrebet er komplekst og svært at definere, er det ofte en udfordring for disse institutioner. Jeg giver konkrete forslag fra tre perspektiver: forskning, policy og praksis. Danmark anerkendes ofte for at være foregangsland for bæredygtighed, og er derfor et velegnet sted at undersøge bæredygtighedsundervisning og -formidling i de eksterne læringsmiljøer. Først omformer jeg bæredygtighed så det bliver meningsfuldt for de eksterne læringsmiljøer. Dernæst kortlægger jeg det danske landskab med hensyn til undervisningsforløb om bæredygtighed. Endelig udvælger jeg stærke undervisningsforløb med henblik på at udvikle retningslinjer for bæredygtighedsundervisning. Jeg håber de retningslinjer jeg udvikler kan støtte de eksterne læringsmiljøer i deres arbejde med at tilpasse bæredygtighed til deres praksis. Nærværende projekt kvalificerer de eksterne læringsmiljøers arbejde med omstillingen til en bæredygtig fremtid.

Abstract

Recent literature has pointed to out-of-school science education as an important actor in moving towards a sustainable future. However, the fuzziness and complexity of sustainability often challenges the educational efforts of out-of-school settings, such as museums, science centres, zoos, aquaria and planetariums. Denmark is a country often lauded for progress towards sustainability, providing a strong platform for researching sustainability education practice in out-of-school settings. The project is framed by the anthropological theory of didactics, which concerns itself with the diffusion of scientific knowledge through society and social institutions (e.g. museums), and tackles three research questions.

First, I operationalise sustainability in ways meaningful to the educational missions of these institutions, by accounting for the features of sustainability science and policy, as well as the different specific strengths of out-of-school settings. After synthesising preliminary criteria for good practice, I subsequently illustrate these findings in the form of an institutionally specific reference model.

Next, I map the landscape of sustainability education in out-of-school settings across Denmark, in terms of the on-site educational programmes with strong sustainability content offered for visiting school classes between 10-12 years old. The study finds a relative scarcity of out-of-school sustainability programmes in Denmark, with zoos and aquaria offering the majority, as well as the influential role of the formal education sector on developing these programmes.

Finally, I select strong candidates for effective sustainability education based on the previous work, to describe good practice through a search for expressions of sustainability agency among children. This research culminates in the development of guidelines for sustainability education in out-of-school settings, and engages stakeholders in employing these guidelines through a Final Workshop event. I hope that the guidelines can support out-of-school settings in the difficult process of operationalising sustainability for their education practice.

Ultimately, the project qualifies the practices of out-of-school settings in their endeavours to prepare us all for a sustainable future.

Abstract in Danish

Nyere forskning har peget på hvordan eksterne, naturfaglige læringsmiljøer (fx museer, science centre, zoologiske haver, akvarier og planetarier) er vigtige aktører i omstillingen til en mere bæredygtig fremtid. Men det er en udfordring for disse læringsmiljøers undervisning og formidling at begrebet bæredygtighed hverken er veldefineret eller entydigt. Danmark fremhæves ofte som førende indenfor bæredygtighed, hvilket gør det til et velegnet sted til at undersøge bæredygtighedsundervisning i eksterne læringsmiljøer. Nærværende projekt benytter trækker på den antropologiske teori om det didaktiske (ATD), som beskriver hvordan videnskabelig viden bevæger sig gennem samfundet og dets institutioner (fx museer). Projektet takler tre forskningsspørgsmål.

Først operationaliserer jeg begrebet bæredygtighed, så det bliver meningsfuldt for de eksterne læringsmiljøer og deres undervisnings- og formidlingspraksis. Det gør jeg ved at redegøre for bæredygtighed i forhold til videnskab, i forhold til policy, og i forhold til de forskellige forudsætninger og styrker der kendetegner eksterne læringsmiljøer. Jeg syntetiserer herefter et sæt foreløbige kriterier for god formidlingspraksis, og jeg illustrerer disse kriterier i form af en institutionelt specifik referencemodel.

I næste skridt kortlægger jeg det danske landskab i forhold til de eksterne læringsmiljøers bæredygtighedsformidling. Jeg fokuserer i denne kortlægning på skoletjenesteforløb der afholdes på de eksterne læringsmiljøer, har tydeligt bæredygtighedsindhold, og tilbydes til mellemskolen (10-12-årige børn). Denne kortlægning viser at der er relativt få skoletjenesteforløb om bæredygtighed blandt danske eksterne læringsmiljøer. Zoologiske haver og akvarier udbyder størstedelen af de tilbud jeg finde. Endvidere har det formelle uddannelsessystem tilsyneladende en stærk indflydelse på hvordan disse forløb bliver udviklet.

I sidste skridt udvælger jeg en række kandidater for god praksis blandt skoletjenesteforløb med bæredygtighedsindhold. Denne udvælgelse er baseret på de forudgående skridt. Blandt disse skoletjenesteforløb søger jeg at finde tegn på bæredygtighedskompetencer (eng: sustainability agency) blandt deltagerne. Dette arbejde fører til udviklingen af et sæt retningslinjer for bæredygtighedsundervisning og -formidling i eksterne læringsmiljøer. Disse retningslinjer præsenteres for professionelle undervisere fra de eksterne læringsmiljøer i en afsluttende workshop. Det er mit håb at retningslinjerne kan understøtte de eksterne læringsmiljøers i den krævende proces det er at gøre bæredygtighed meningsfuldt i undervisning og formidling.

I sidste ende kvalificerer dette projekt de eksterne læringsmiljøers arbejde med at omstille samfundet til en mere bæredygtig fremtid.

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The past three years as a PhD fellow have been thoroughly enjoyable and I've had the pleasure of working alongside some inspirational people. Firstly, I must send my deepest thanks to my supervisor, Marianne Achiam for her constant support and guidance. Your ability as a science education researcher provided many a moment of inspiration and confidence, and I fully appreciate the working relationship that we've developed. Next, I'd like to express my thanks to the late Sara Tougaard, who was always available for professional and personal chats. Sadly as is often the case, it was only once you'd gone that I fully appreciated how vital these had become. To my *skrivekammerater*, Andrea, Katia, Marianne and Sinne, for transforming 2020, the year of COVID-infections and lockdowns, into one full of laughter and productivity. Embedded within this thesis are the many hours we spent online together. To colleagues at the Department of Science Education - many thanks for enduring my 'Danglish', and for contributing to a working environment that allows individuals to thrive. Special thanks to Line Nicolaisen and Christina Larsen for always being on hand with kind words of support. To Cecilie Lam and George Ma at the Museum of Climate Change in Hong Kong – thank-you for your time and guidance during my three-week stay. To Melissa Glackin and Heather King at Kings College London – thank-you for welcoming me to your department, particularly during the difficult scenario of a national lockdown. To the educators at museums, science centres, zoos, aquaria and planetariums across Denmark – my thanks for your valuable time and efforts towards the project. Notable mentions to Louise Nordbjerg Bergman at Copenhagen Zoo in the early stages of the research, and Søren Forsberg at Kattegatcentret in the latter stages. To the school teachers who dedicated their time and energy towards the research, thank-you. To all the students in Grade 4, 5 and 6 who participated in data collection – your enthusiasm to learn and care for the natural world are what drove me on during the difficult times. To my loving family, for your infinite amounts of emotional support in life, and an enduring interest in the project – you are the backbone of this research. Finally, to my wonderful fiancée and soon to be wife, Tinne Hjersing Knudsen. You are a truly wonderful woman, and the love and support you provide on a daily basis are more appreciated than you'll ever know.

List of Abbreviations

ATD – Anthropological Theory of Didactics

DAZA – Danish Association of Zoos and Aquaria

DDT - Dichlorodiphenyltrichloroethane

ESD – Education for Sustainable Development

FSC - Forest Stewardship Council

ICOM – International Council of Museums

IPBES - Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC - Intergovernmental Panel on Climate Change

NGO - Nongovernmental organisation

OSSEI – Out-of-School Science Education Institution

SCWS – Science Centre World Summit

SDGs – Sustainable Development Goals

UN – United Nations

UNEP - United Nations Environment Programme

UN-GSDR – United Nations Global Sustainable Development Report

WAZA – World Association of Zoos and Aquaria

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Prologue

This starting section acts as an introductory welcome to myself, the researcher, and my personal journey of development within science and exploration prior to the project.

The Natural Sciences

I developed a fascination for the natural world from an early age, in particular the weird and wonderful creatures inhabiting the depths of the oceans. At the age of 10, I was the proud owner of a large tropical fish tank, to recreate scenes from the BBC documentary series, *The Blue Planet*. Seven years later, I found myself learning to dive in Central America and Southeast Asia, and soon after started a bachelor degree in marine biology at the University of Plymouth, south-west England. My thesis investigated the diet of the juvenile common cuttlefish, *Sepia officinalis*, by a combination of quantitative seagrass surveys, and the rather messy procedure of stomach content analysis. The positivist paradigm, with objectivity and the existence of one truth, heavily shaped my approach to research. I had well thought out plans to continue down this path, however a life-changing opportunity presented itself. I found myself heading down to the coldest part of the planet with a pair of skis – Antarctica.

Exploration

During the bachelor degree, I applied to a national competition for an opportunity to ski the last two degrees (222 kilometres) to the South Pole in Antarctica, as part of the 100-year commemorations of the British explorer, Captain Robert Falcon Scott. The selection process, involving The Royal Navy and The Daily Telegraph, received over 300 entrants. I proceeded through the selection stages, which involved weeklong navy-led courses and other activities. Involving four candidates, the final stage took place in Northern Norway in the form of week-long polar training expedition, and was my first ever trip to Scandinavia. Once back in the UK, I was informed as being the chosen candidate. In early December 2012, after months of fundraising and training, I set off from London for the Antarctic continent via the tip of Chile. As part of the expedition, I carried out polar experiments on behalf of the British Antarctic Survey, collecting samples of sub-surface snow every five kilometres to study the warming of the region. After two-weeks of skiing across the Antarctic interior as part of a 2-person team, I reached the South Pole on the 9th January 2013.

Science Communication and Scandinavia

On my return to the UK, I soon realised I had a story to tell, and so set about delving into the world of science communication. In addition, I had the desire to build upon my first Scandinavian experience, and so I undertook trips to Oslo, Copenhagen, Stockholm, Helsinki and Reykjavik to run their marathons. Between these adventures, I wrote a book titled ‘From University to the South Pole’ and began to develop my own

science communication company. These experiences led to myself spending much of the next couple of years travelling around the world to deliver presentations and workshops to students of all ages in international schools and other institutions. Sessions focused on polar exploration and the marine and climate sciences. My desire for academia grew again, and in the autumn of 2015, I started a 2-year Master degree in Climate Change at the University of Copenhagen. It was a very interesting time to be studying the topic, with the formation of the Paris Agreement and Sustainable Development Goals (SDGs) at the same time. The degree took an interdisciplinary approach, with lecturers contributing from many different disciplines across the university.

The Social Sciences

Research ideas for a Master thesis project on climate change education and schools led to myself making contact with associate professor Marianne Achiam at the Department of Science Education (Institut for Naturfagenes Didaktik). The subsequent project investigated how different framings of climate change affect pro-environmental behaviour, with mixed-methods research taking place involving 604 students and 71 teachers across seven international schools in Southeast Asia. This was my first experience of collecting qualitative data, and towards the end of the project, Marianne and I began to discuss ideas for a future PhD. The notion of sustainability was fast growing in use by stakeholders in society, and I was interested in its operationalisation for educational means. Six months after the Master degree, we began to work on a funding application, with myself bringing the climate change-sustainability dimension, and Marianne an understanding of out-of-school science education. In December 2018, the application received full funding from Novo Nordisk Foundation, and on the 1st April 2019 - my PhD journey began.

The PhD Fellow

My academic background on humanity's impact on the natural world, and practical experience of science communication in schools, combine to form a PhD in sustainability education and early-adolescents. Working within the interpretivist paradigm, through subjectivity and the existence of multiple truths has been a difficult transition process. At times, it has been a struggle to find my domain, and other researchers working within similar fields. A PhD fellow can at times be a lonely existence, but it is one that I have thoroughly enjoyed. I have thrown myself into many different tasks, including research, teaching, supervision, courses, conferences and keynotes – such fun!

I hope that the reader finds the thesis to be an insightful passage into the world of sustainability and out-of-school science education.

Henry James Evans, 31st March 2022

1.0 Introduction

This chapter provides information on the structure of the thesis and motivations behind the project, as well as the problem it aims to solve and how the research intends to deal with this.

1.1 The Concept of Education at Play

Sustainability and education are both huge fields. The focus of the thesis is sustainability education in out-of-school contexts, and more specifically how these institutions deconstruct and reconstruct the notion of sustainability in their educational work. I turn to the phrase 'out-of-school science education institutions' (OSSEIs) to describe the following institutions: natural history museums, science and technology museums, science centres, planetariums, zoos, aquaria and botanical gardens.

1.2 The Concept of Sustainability

Sustainability is a fuzzy and complex notion with a range of interpretations (Phillis & Andriantiatsaholiniaina, 2001; Purvis, Mao & Robinson, 2018) meaning different things to different people across multiple spatial scales. For example, some may talk about sustainable development on global, national, local and community levels, while others may refer to acting sustainably as a collective or individual. In the eyes of some researchers, its philosophical ambiguity and range forms the strength of sustainability (e.g. Peterson, 1997). The SDGs, in the form of 17 goals, 169 targets and 232 indicators, provide a conceptualisation, or delimitation of sustainability. For education environments inside and outside of schools, the notion of sustainability remains amorphous for education (Brown, 2019; Jickling & Wals, 2008). Jonas Andreasen Lysgaard, associate professor at the Danish School of Education, Aarhus University, states the following:

> When we speak of sustainability, we often end up discussing things we must not do. Such a purely negative formulation does not work in a pedagogical context. We should rather view the issue as an opportunity to take a critical approach to work, to rethink and to innovate (Weirsøe, 2021)

This project does not aim to provide a working definition for sustainability. As outlined earlier, many researchers have worked on the concept for decades, and we draw on this body of scholarly knowledge to apply it to the specific context of out-of-school science education. Paper One and Paper Three take a normative point of departure on sustainability, detailing how sustainability should look in a particular context. Paper Two takes an analytical stance in the form of a thematic analysis.

1.3 Navigating the Thesis

The backbone of the thesis is in the form of three studies, which directly correspond to three research questions (RQs) addressed in three individual papers. Study One develops an understanding of the notion of sustainability and the optimal fit with OSSEI practice, while Study Two provides an overview of Danish out-of-school sustainability education. Study One and Study Two feed directly into the formation of Study Three, which draws on the concept of agency to develop guidelines for sustainability education in OSSEIs (Figure 1). Finally, a fourth additional study examines museum neutrality; an issue with clear links to the dissemination of sustainability topics such as climate change.

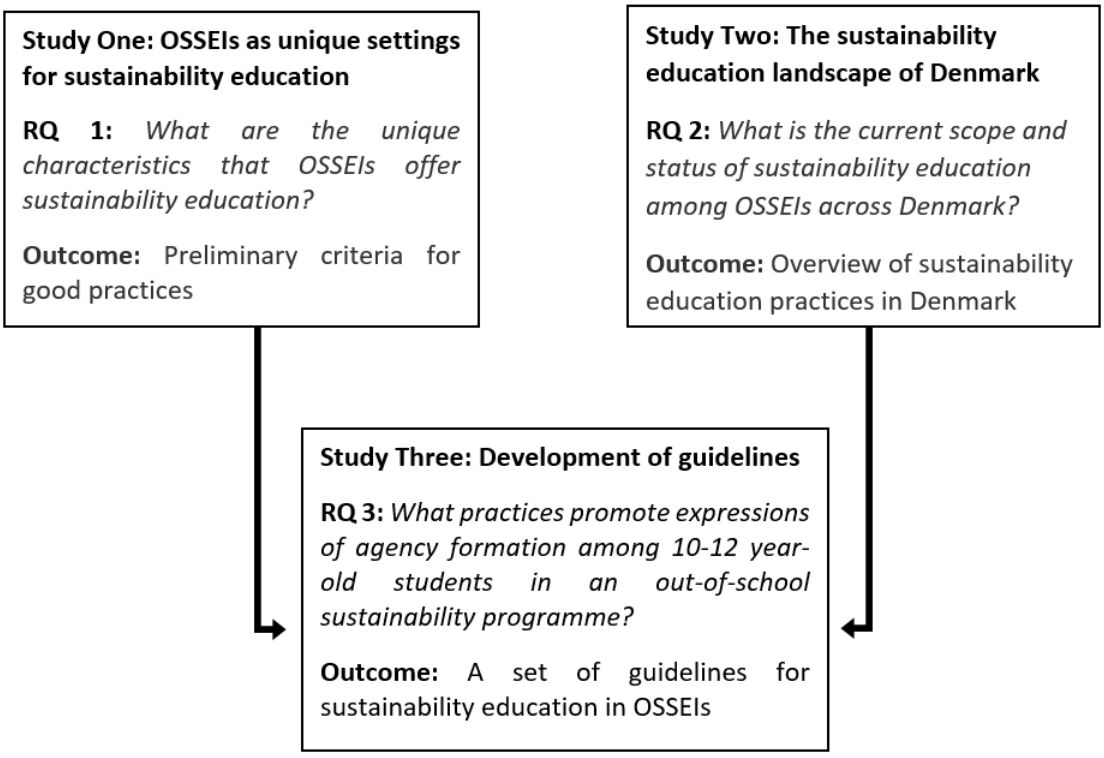

Figure 1. The three studies with corresponding RQs and outcomes.

1.4 Motivation

We are living in a time of uncertainty over the future of life on planet Earth, due to global sustainability challenges such as the sixth mass extinction event (Ceballos et al., 2015), anthropogenic climate change and plastic pollution. Humanity has markedly increased its applied knowledge on sustainability, exemplified by recent reports from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the Intergovernmental Panel on Climate Change (IPCC), and a global assessment of marine pollution by the United Nations Environment Programme (UNEP). Conceptualisations such as planetary boundaries

(Rockström et al., 2009) and the Doughnut model (Raworth, 2012) further emphasise the critical need for a more sustainable future.

In response, transformational change is beginning to take place. The year of 2015 was a watershed moment for global cooperation on sustainability and climate change, with the formation of the Paris Agreement and the 2030 Agenda for Sustainable Development. Furthermore, a global pledge to end deforestation by 2030 was agreed at the recent COP26 Climate Summit, and a global treaty on plastic pollution is expected to be confirmed soon (Briggs, 2022). Over the past 12 months, many countries and businesses have developed plans for achieving carbon net zero by 2050, while investments shift significantly towards more sustainable alternatives. Meanwhile, the momentum behind environmental activism has led to the emergence of inspirational youth such as Greta Thunberg and Leah Namugerwa, and initiatives such as Fridays For Future and global climate strikes (cf. Singh et al., 2019). Setbacks in the form of the elections of Trump in 2016, and Bolsonaro in 2019 shine light on the importance of localised action. Relevant examples include the Californian governor 'seizing climate leadership' (Patrick, 2017) and Brazilian museums challenging the current political agenda (Basciano, 2021). In addition, the US organisation 'We Are Still In' was set up as a platform for remaining aligned to the Paris Agreement, and received the backing of various stakeholders, including 87 cultural institutions (or OSSEIs) such as museums, science centres, zoos, aquaria and botanical gardens (We Are Still In, n.d.).

I have always enjoyed visiting OSSEIs, whether on a school trip, with family, friends or my fiancée. I have memories of multiple visits to the Natural History Museum, London Zoo and the Imperial War Museum, as well as more recent trips to the Eden Project in south-west England, the Smithsonian in Washington DC and Ocean Park in Hong Kong. As my understanding of sustainability issues has grown, I have become interested in the role of OSSEIs in aiding a global transition towards a greener, more equitable future. I can distinctly remember visiting museum exhibits displaying climate change as more of a debate, leaving the visitor to form their own opinion, or zoo visits where the primary contribution to nature conservation was through buying an ice cream. Are cultural institutions merely a place for neutrality, dusty collections and caged animals, or can, and should they take a stance though action-orientated practice? Without embracing the notion of sustainability across all external and internal initiatives, will these important community-based institutions eventually become insignificant in a rapidly changing society?

In 2015, I began to notice an increasing number of OSSEIs focusing on sustainability and climate change, and furthermore, the appearance of the 'climate museum'. In addition, I came across Ecolarium, a Danish science centre placing sustainability at the forefront and formed 20 years ago. I began to develop further questions, such as how were these particular out-of-school sustainability focused institutions disseminating complex,

real world issues to their visitors? What were the takeaway messages for incorporating sustainability into internal and external out-of-school practice? What role does the Danish school curriculum play?

1.5 The Context of Denmark

Denmark has been my home for the past 6 and a half years, and efforts to integrate include attending language classes, eating herring on rye bread, winter bathing, celebrating Christmas on the wrong day and hearing every joke possible about the city of Randers. These experiences will soon culminate in marrying a Dane on the 28th May 2022. Strange traditions aside, Denmark is renowned for progress towards sustainability, providing a strong platform for researching education practice – as highlighted by the journal *Environmental Education Research* special issue on environmental and sustainability education in Denmark and Sweden (2010, volume 16, issue 1). The first paper of the present thesis, Evans & Achiam, (2021), is published in this particular journal. Furthermore, and as highlighted in the second paper, Evans, (in press), the range and depth of out-of-school science education opportunities across Denmark present an interesting backdrop for researching sustainability education.

1.6 Framing the Problem

As a global community, we are facing massive problems associated with the notion of sustainability, yet there are significant gaps between scientific knowledge and public opinion (Clayton, 2017; Stevenson et al., 2016). These gaps have been attributed to both scientists' failure to communicate with learners using suitable language (Kadlec, 2009), but also widespread misconceptions within public and political spheres. However, as discussed in Paper One, some areas of education policy and practice contain elements of reductionism (Brailas, 2021; Sterling, 2021), which potentially lie in opposition to the agenda required for sustainability transitions. Furthermore, while the notion of sustainability will be touched upon in school subjects such as the sciences, geography and politics, the overarching dissemination of sustainability issues often only takes place in schools during a sustainability themed week (Weirsøe, 2021).

New solutions are needed to prepare young citizens to address the serious issues we face. OSSEIs act as a bridge between science and society (Logan & Sutter, 2012), transcend disciplinary boundaries and receive hundreds of millions of visitors worldwide each year. OSSEIs are often indicated as an important actor in moving towards a sustainable future, such as the SDG target 11.4 - to 'strengthen efforts to protect and safeguard the world's cultural and natural heritage' (UN, 2015). In contrast to this, sustainability is a difficult notion to deconstruct and reconstruct, and so rarely becomes operational in a way that fits with the mission and vision of OSSEIs, leading to their educational efforts often challenged by its fuzziness and complexity.

1.7 Overarching Aim

The present thesis studies sustainability education from epistemological (Paper One), institutional (Paper One, Two and Four), and pedagogical (Paper One and Three) perspectives. It is not a learning theory research project per se, although does draw on learning theory where appropriate. Through the structuring of three main papers, this project utilises the proven potential of OSSEIs to engage early adolescents in questions that matter to promote changes in knowledge, attitudes and behaviours, which in turn develop agency and hope. The research attempts to operationalise sustainability in optimal ways meaningful to the specific educational missions and conditions of these institutions (Paper One), and identifies preliminary criteria for good practices in sustainability education among OSSEIs (Paper One and Paper Two). Furthermore, the research investigates how and why these practices work (Paper Two and Three), and formulates the generated knowledge into a comprehensive set of guidelines for sustainability education in out-of-school settings (Paper Three). Finally, the project engages stakeholders in employing these guidelines for effective sustainability education through a Final Workshop event. Ultimately, the research qualifies the practices of OSSEIs in their endeavours to prepare us all for a sustainable future.

1.8 Summary of Contributing Papers

This section outlines how the papers (see Chapter 9) contribute to the overarching aims of the project.

1.8.1 Paper One (Study One, RQ1)

This paper, titled 'Sustainability in out-of-school science education: identifying the unique potentials', looks across science, policy and practice to create a reference model of knowledge on sustainability. The reference model operationalises the notion of sustainability to fit with the different types of out-of-school education practice, and subsequently illustrates what sustainability might look like in natural history museums, science and technology museums, science centres, zoos and aquaria.

1.8.2 Paper Two (Study Two, RQ2)

This paper, titled 'The scope and status of sustainability education in out-of-school settings across Denmark', maps sustainability education in OSSEIs across Denmark, with focus towards on-site programmes for visiting school classes in Grade 4-6 (Danish intermediate level) with strong orientations towards sustainability. The research finds a relative scarcity of sustainability programmes in OSSEIs across Denmark, and proceeds to analyse five programmes representative of the sustainability education landscape, in terms of type of institution, geographical location and topic(s) associated with sustainability. Findings indicate the influential role played by schools and the curriculum on OSSEI practice.

1.8.3 Paper Three (Study Three, RQ3)

This paper, titled 'Expressions of agency in out-of-school sustainability programmes: moving towards guidelines for sustainability education', uses the notion of agency to develop guidelines for sustainability education; subsequently disseminated in a Final Workshop event for invited Danish out-of-school practitioners on Friday 25th March 2022. Results from Paper One and Paper Two are used to select strong candidates for sustainability practice, from which the identification of good practice in OSSEIs takes place.

1.8.4 Paper Four

This position paper, titled 'Museums beyond neutrality', problematises the concept of *feigned neutrality* in museums, and discusses how a more action-orientated approach would look across the three museum columns of research, collections and dissemination. Inclusion plays an important role in many sustainability issues and the conclusions of this paper are thus applicable to the overarching sustainability discussion in this thesis.

1.8.5 Additional Research Output

A book chapter, titled 'Out-of-school science education institutions for sustainability', illustrates how OSSEIs are ideally placed in contributing to a more sustainable future. The work is currently in press (Achiam & Evans, in press) and due to be published in the volume *Amplifying Informal Science Learnings (eds. Diamond & Rosenfeld)*. In addition, a popular science article, titled 'Operationalising sustainability for zoos and aquaria', was published in the *World Association of Zoos and Aquaria News Magazine* (Issue 2, p17-19) (Evans, 2021). A link to the article is provided here: https://www.waza.org/wp-content/uploads/2021/08/WAZA-magazine-2021_Digital_Final.pdf

1.9 Terminology

There is much variation in the terminologies used to describe out-of-school learning, such as informal learning, non-formal learning, informal education, free-choice learning, learning in out-of-school contexts, settings, or environments (Anderson & Ellenbogen, 2012; Rennie, 2007). Many aspects of experiences found in OSSEIs can be labelled as formal, such as the structured elements of some museum or zoo education programmes for visiting school classes (Anderson & Ellenbogen, 2012). This project researches sustainability education within the context of Danish museums, science centres, zoos and aquaria, botanical gardens and planetariums – collectively known as out-of-school science education institutions, or OSSEIs.

1.10 Target Age-Groups

In the early stages of project, I began to carry out an initial informal analysis of the different programmes offered for school classes aged between 6-16 years old ('folkeskole' in Danish) by OSSEIs across Denmark.

Many OSSEIs divide their programmes up into the three categories of lower school ('indskoling', Grade 1-3), intermediate ('mellemtrin', Grade 4-6) and upper school ('udskoling', Grade 7-10). In particular, I noticed the large number and variety of programmes offered for intermediate classes, with students aged between 10 to 12 years old. To delimit my research focus, I already had this age group in mind, due to previous experience gained from working with students in international schools for the dissemination of sustainability and climate change. Furthermore, I read two interesting studies by Lawson et al., (2018, 2019) on the potential for intergenerational learning and climate change action. Subsequently, the research in Paper Two and Paper Three focuses on this particular age group. At the age of 10, students often show positive attitudes and interests towards science, with these features often fully developed by 14 years old, while reductions in motivation occur over the following years (Archer et al., 2010). The early adolescent stage is very important in the development of attitudes towards the environment and sustainability (Cobb, 1977). These age groups thus have a greater willingness to act on and engage in sustainability education, directly and indirectly influencing family, friends and beyond.

1.11 Project Reflections

This section provides some reflections on the project, mostly focusing on the early-stages.

1.11.1 Difficulties with the Notion of Sustainability – Summer 2019

The experience of communicating topics such as climate change in international schools gradually sensitised me to the fact that sustainability is amorphous and abstract. Furthermore, the scientific literature, and my experiences of visiting OSSEIs, made me aware of how sustainability is not easily translated into out-of-school practice. To reflect this, a reshaping of Paper One took place to be more exploratory in nature - to look across science, policy and practice in an attempt to operationalise sustainability to a better optimal fit for the educational missions of OSSEIs.

In the summer of 2019, while still in the early stages of Paper One, I began to search for examples of Danish OSSEI sustainability practice to help with my formulation of research ideas. On multiple occasions, I observed a new school programme for intermediate classes at Copenhagen Zoo on rhino conservation - the first programme at the zoo incorporating the SDGs into practice. The zoo's Head of Dissemination and Teaching, Louise Nordbjerg Bergman, was very open in sharing her process of trial and error, and discussing where and how the notion of sustainability potentially fits with the mission and vision of the institution. It proved to be valuable to observe the programme, in particular how intermediate students interacted with the programme. Finally, it was useful to practice interacting with Danish students in this particular age group, with these experiences crucial in improving my methodology and communication during Paper Two and Paper Three.

Co-currently, I carried out a pilot study with educators from OSSEIs across Denmark, with this further explained in the Methodology chapter, Section 3.7.

1.11.2 Heading off to Hong Kong – Autumn 2019

For my first research stay abroad, in September-October 2019 I visited the Museum of Climate Change at the Chinese University of Hong Kong. It was unclear what the exact aims and schedule were for the trip, which on reflection turned out to be a real strength, and perhaps even expected when only six months into a PhD project. The data collected in the form of interviews and observations have not been formally incorporated into the thesis, however the research visit proved valuable in aiding the formulation of my research ideas and methodologies. Furthermore, it proved useful to gain an international perspective on sustainability and museology, by spending time within the internal workings of the first ever climate museum. Finally, the visit was heavily disrupted by the ongoing political struggles between Hong Kong and China, which led to the closure of the museum for one-third of the trip.

1.11.3 The Coronavirus Pandemic – Spring 2020 to Winter 2021

Two-thirds of my PhD have taken place during the coronavirus pandemic, a global event that has heavily affected both my personal and professional life. The pandemic led to working from home for long periods of time, the missing of valuable dialogue with colleagues, the closure of OSSEIs, regular cancellations of school programmes, and much disruption to conferences and seminars. In addition, I was unable at times to travel home to see family and friends, which caused much anxiety over the health of my loved ones. Overall, I am incredibly proud with how I have dealt with these challenges. Through much adaptability and hard work, I have still managed to submit a PhD thesis on time, and published three research papers.

1.11.4 Delimiting the Project Focus

The terminology of OSSEI led to questions over the types of out-of-school institutions of interest for the thesis. A variety of art institutions exist across Denmark, with many increasingly incorporating sustainability into internal and external practice. In August 2019, I had a meeting with an educator at Design Museum Denmark, to learn more about their sustainability practice and institutional fit. Other institutions facing similar questions include botanical gardens and planetariums, with Paper One receiving comments on excluding them in the illustrations of out-of-school sustainability practice. I am familiar with such studies in botanical gardens as Sellmann & Bogner, (2013) and Zelenika et al., (2018), however the small number of botanical gardens in Denmark, plus those existing having no school programmes on sustainability topics - led to their exclusion. The Planetarium in Copenhagen is included in the analysis in Paper Three, due to their new school programme *Satellites and the Sustainable Development Goals*.

2.0 State of the Art

This chapter situates the project in the literature across science, policy and practice within a European/US context, and outlines where the field is currently. It provides background on the history of sustainability, the formation of sustainability science, the progression of sustainability education, and finally, how sustainability is presented within the context of OSSEIs. The terms 'sustainability' and 'sustainable development' are regularly woven together within the literature (Purvis, Mao & Robinson, 2018), with both used in the sections below.

2.1 A Brief History of Sustainability

Sustainability has been described as a 'modern concept with deep historical roots' (Grober, 2007, p. 6). In the mid-17th century, an understanding began to develop on the negative impacts of environmental destruction for economic purposes (Wiersum, 1995), such as cutting down trees for timber (Grober, 2007). In the early 18th century, German forestry provided the context for the first recorded formulation of sustainability, in the book *Sylvicultura Oeconomica* written by Hans Carl von Carlowitz (Du Pisani, 2006; Hölzl, 2010).

By the mid-20th century, publications such as 'Silent Spring' contributed to a growing awareness of the anthropogenic impacts on planet Earth. The book, published in 1962 by Rachel Carson, broadly focused on humanity's connections with the natural world, and more specifically the devastating impacts of the pesticide dichlorodiphenyltrichloroethane (DDT) across the United States (Carson, 1962). The chemical was subsequently banned, and the foundations for modern environmentalism were in place (Dillon, 2005; Kroll, 2001; Paull, 2013). In 1972, the first United Nations (UN) conference on environmental impacts associated with human activity took place in Stockholm. That same year saw the release of the report 'The Limits to Growth' (cf. Meadows et al., 1972), which used computer modelling to predict future limits between ecology and economy (Ekins, 1993). In Denmark, this same period saw the creation of the Ministry of the Environment, caused by increasing anxiety over environmental issues (Breiting & Wickenberg, 2010). Sustainability was now becoming more frequently discussed at the global level (Agbedahin, 2019; Purvis, Mao & Robinson, 2018) in both anthropogenic and environmental contexts (Pezzey, 1992; UNESCO, 2016). Despite the accumulating knowledge and understanding of sustainability issues, minimal action took place and mostly instigated by individuals or specialised nongovernmental organisations (NGOs) (McFarlane & Ogazon, 2011).

In 1987, the Brundtland Report (or *Our Common Future*) by the UN World Commission on Environment and Development, used the term 'sustainable development', and provided a foundation for the emergence of

sustainability policy (Kuhlman & Farrington, 2010). The report defined sustainable development as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland, 1987, p. 41). The concept has proven effective at ensuring discussions maintain global perspectives in terms of the future of planet Earth (Mebratu, 1998). However, Jickling, (1994, p. 2) describe sustainable development as a "vague slogan susceptible to manipulation". Timberlake, (1988) discusses the role of science and scientists in the formation of the Brundtland Report, outlining them as not the main factors behind the outcomes reached, but instead more as a referee. That same year (1987), Barbier suggested sustainability incorporates the three pillars of environment, society and economy (also known as planet, people and profits) – through the configuration of three overlapping circles (Purvis, Mao & Robinson, 2018). Suggestions for additional pillars include for example, cultural sustainability (Pop & Borza, 2019).

At the 1992 UN Earth Summit in Rio de Janeiro, politicians from around the world agreed to back the ideas behind sustainable development (Jordan & Voisey, 1998), and to work towards new relationships for consumption and safeguarding the natural resources on planet Earth (Grober, 2007). The conference resulted in *Agenda 21***,** a plan of action with an understanding of the important role education plays in sustainable development (Agbedahin, 2019; UNCED, 1992). *Agenda 21* led to the supporting of sustainability at the political level as the most important factor in furthering the development of humanity (Martins, Costa & Mata, 2006).

Turning to modern uses of sustainability, the concept is slightly messy, existing in numerous forms and layers. Examples include the orientations of 'weak' and 'strong' sustainability (Marouli, 2021; Neumayer, 2003), as well as 'loose' and 'tight' framing (Scott, 2015). Sustainability requires context, and the asking of critical questions such as 'for whom and of what' (Purvis, Mao & Robinson, 2018). Since 2015, the planet has seen growing levels of environmental activism (Teerikangas et al., 2021), coinciding with the formation of the seventeen SDGs. Stemming fundamentally from the three pillars (UN, 2012), the global goals, with their 169 targets and 231 indicators, make up a large part of the 2030 Agenda for Sustainable Development. Most importantly, they receive the support of all 193 UN member states (UN, 2015). The SDGs are far greater in stature and complexity than the 8 Millennium Development Goals, and their 18 targets and 46 indicators (Maurice, 2016).

Released in 2019, the UN Global Sustainable Development Report (UN-GSDR) outlined that early progress towards achieving the goals has been poor (UN-GSDR, 2019). A critical element behind the success of the goals will be the outcomes of synergies and trade-offs that form interactions between them all (Kroll, Warchold & Pradhan, 2019).

As shown above, sustainability policy has seen a rapid progression over the past half a century. Shifting our attention to the present day, I will lay out the argument that in addition to policy, sustainability now lies firmly grounded too within research. This is illustrated by the existence of research centres and peer-reviewed journals dedicated to the emerging research field of sustainability science (Fang et al., 2018). In some ways, this is not surprising, when taking into account the importance of policy for research, in terms of driving funding allocation and the directions taken. Furthermore, an increasing number of higher education institutions are becoming more dependent on obtaining external funding. Present-day sustainability policy, such as the SDGs, draw strongly on research publications and comprehensive assessments reports rooted in the scholarly domain, such as those produced by the IPCC and IPBES. Therefore, we will now turn our attention to that of sustainability science.

2.2 Sustainability Science

Sustainability science combines the domains of the natural world and society to tackle problems working across and between disciplines (Barrett, 2021; Kates, 2001). This relatively new field of research unified in 2000 (Bettencourt & Kaur, 2011), leading to the creation of journals purely focused on sustainability, such as *Nature Sustainability* and *Sustainability Science* (UN-GSDR, 2019). Sustainability science research occurs globally in an increasing number of university and non-university settings (UN-GSDR, 2019), with the local example of the Sustainability Science Centre, University of Copenhagen, founded in 2012. The field has a large geographic distribution (Kates, 2011), active within countries not traditionally known for publishing scientific knowledge (i.e. Nigeria, Kenya and Brazil), and those known as established producers (i.e. Western Europe and the US) (Bettencourt & Kaur, 2011). Differences are found in the types of knowledge produced; more technological in the global North, compared to more traditional in the global South (Kates, 2001).

To gain a better understanding of sustainability science, Bettencourt & Kaur, (2011) analysed the scholarly knowledge produced between 1974 and 2010, by looking at approximately 20,000 journal and conference papers written in English. With searches for 'sustainability' and/or 'sustainable development' within the title, abstract or keywords, publications found represented 37,000 individual authors from 174 countries and 2,206 cities. A large increase in the numbers of publications occurred in the late 1980s and early 90s, linked to the release of the Brundtland Report and *Agenda 21*. A similar study by Kajikawa et al., (2014) found a dramatic increase in publications from 2005, and by 2014 over 12,000 papers were being published per year. González-Márquez & Toledo, (2020, p. 4) summarise these results as an 'increasing acceptance of the concept of sustainability as an appropriate way of positing the problem, pointing towards specific solutions'.

Regarding the foci of sustainability science, Kajikawa et al., (2007) analysed the scholarly knowledge of sustainability, identifying 15 subdomains, such as Agriculture, Energy, Fisheries and Tourism. In addition, they used natural language processing to identify seven topics that were prevalent in the literature, with two examples that of Climate Change and Education. Ten years on, Kajikawa et al., (2017) focused on the journal *Sustainability Science* to investigate how the field is changing, finding the most dominant research clusters of 'Environmental and Social Systems' and 'Economy and Business Systems'. Messerli et al., (2019) write that to achieve the ambitious targets included within the SDGs, sustainability science is required to broaden itself in the future.

2.3 The Journey of Sustainability Education

Sustainability education is a pedagogy associated with, or based on the notion of sustainability; used as an overarching phrase to describe all forms of education orientated towards the environment and sustainability (e.g. Aikens, McKenzie & Vaughter, 2016). Rather than primarily focusing on environmental protection, sustainability education has the addition of social and economic dimensions (Martins, Mata & Costa, 2006). This form of education provides a platform for learners to tackle how to best use and sustain resources on planet Earth (Coll, 2016), encourage people to make lifestyle changes and to 'think globally and act locally' (Mckeown & Nolet, 2013, p. 6). Throughout the literature exists various conceptualizations of education orientated towards sustainability, such as education for sustainable development (ESD) and education for sustainability. This section begins by introducing the concept of environmental education, before continuing onto the transition towards sustainability.

2.3.1 Environmental Education

As previously outlined, societal considerations for the environment grew from the 1950s onwards (Dillon, 2005), while images of planet Earth from space exploration in the 60s and 70s provided a better understanding of its fragility and limited resources (Smyth, 2006). In the beginning, much focus was placed on nature conservation and researching how exposure to nature can be beneficial to students (Madsen, 2013; Stevenson et al., 2016). In 1969, William Stapp and colleagues wrote a paper titled 'The Concept of Environmental Education', which defined environmental education as a pedagogy 'aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution' (Stapp et al., 1969, p. 34). In 1972, Arthur Lucas published a classification of environmental education, in the form of education *about* the environment (cognitive understanding), education *for* the environment (preservation), and education in the environment (technique of instruction) (Lucas, 1972). Glackin & King, (2020) analysed environmental

education policy in UK secondary schools, finding a lack of policy directives, and the majority of those existing focused on *about* the environment.

Environmental education aims to re-shape our relationship with the non-human world (Marouli, 2021), by improving knowledge, behaviour and attitudes towards the environment (Stern, Powell & Ardoin, 2008). However, sustainability education aims to go beyond these three measurables, by aiding society in developing the competences required for effective leadership and management (Steinfeld & Mino, 2009).

2.3.2 Orientations towards Sustainability

After the release of the Brundtland Report, environmental education gained momentum (Wang & Chiou, 2018) and began to shift more towards sustainability. *Agenda 21* highlighted the need for a 're-orientation of environmental education towards sustainability' (Tilbury, 1995, p. 198) by recommending the inclusion of ESD in all tiers of education (Walker, 2017). During this time, the phrases of education for sustainability and ESD began to replace environmental education (Martins, Mata & Costa, 2006). Although ESD is contested (Dillon & Huang, 2010; Jickling & Wals, 2008; Madsen, 2013), the concept has become a widely used term for education referring to sustainability related topics, such as climate change and an unequal distribution of natural resources (Madsen, 2013). These educationally orientated conceptualisations of sustainability have received supported from the UN, and were thus incorporated into their educational programmes, such as the Decade of Education for Sustainable Development from 2005–2014 (Holfelder, 2019; Stevenson et al., 2016). However, the initiative has since been deemed rather unsuccessful, and a continuation of the past (Huckle & Wals, 2015). Dillon & Huang, (2010) highlight the low number of teachers that were aware of being in the midst of a Decade of ESD.

In terms of the SDGs, target 4.7 includes a specific mention of ESD and has clear connections to the climate change education target 13.3 (McKenzie, 2021). Western countries provide context for the majority of sustainability education initiatives worldwide (UN-GSDR, 2019), with Sweden regarded as a powerhouse (Breiting & Wickenberg, 2010).

2.3.3 Challenges for Sustainability Education

Close to fifty years have passed since the UN conference in Stockholm, and 30 years since *Agenda 2021*. However, McFarlane & Ogazon, (2011, p. 86) write, 'education rarely challenges the prevailing paradigms and interests of national governments, wealthy elites, or dominant groups, or corresponding economic or political systems'. As discussed in Paper One, reductionism occurs in some areas of education policy and practice (Brailas, 2021; Sterling, 2021), with these approaches unsuitable for dealing with present-day real-world problems, and the initiation of a societal transformation to a more sustainable future (Sterling, 2021).

The 2005 Potsdam Manifesto calls for new ways of thinking (Dürr, Dahm & Zur Lippe, 2005), and a more transdisciplinary outlook guided by real-world problems is critical (Lambrechts, Van den Haute & Vanhoren, 2008; Spangenberg, 2011). The transformative, more inclusive paradigm of sustainability education provides an opportunity for achieving a more equal and just planet Earth. The SDGs provide the strongest orientations for sustainability education across policy and practice (Friedman et al., 2020; Sterling et al., 2017), and yet progress on the majority of the goals are off track (Sterling, 2021). Although we are steadily progressing towards achieving primary education for all (SDG 4.1), challenges remain in secondary and tertiary education (4.1, 4.3), gender imbalances (4.5) and inequality (10.4) (Friedman et al., 2020).

2.4 OSSEIs and Sustainability

Much learning and development of environmental identities and worldviews occurs outside of formal education (Stevenson et al., 2016). When compared to the more reductionist set-up found in schools, the concept of sustainability appears to be a better fit for operationalisation in community-based situations, such as a museum or a zoo (Dillon & Teamey, 2002; Evans & Achiam, 2021). Dillon, (2003) argues that practitioners in environmental education could gain a lot from research on learning in the context of OSSEIs. Furthermore, OSSEIs hold high levels of public trust (Astor-Jack et al., 2006; Cameron et al., 2013; Dilenschneider, 2017; Museums Association, 2013) and as we develop in Paper One, OSSEIs have a whole host of unique potentials in engaging with sustainability. SDG 11.4, 'strengthen efforts to protect and safeguard the world's cultural and natural heritage' (UN, 2015), supports the role OSSEIs can play in working towards a more sustainable future (Petti et al., 2020).

OSSEIs are coming under increasing pressure to prove their worth to society (Evans et al., 2020; Marris, 2021; Sjögren et al., 2015). In response, OSSEIs are starting to play greater roles across a variety of contexts (Iannini & Pedretti, 2022), and the offering of more opportunities for visitors to learn about sustainability issues (Kelsey & Dillon, 2010). However, this sustainability practice is not always explicit in form, with associated global issues not new for OSSEIs, such as climate change, inequality, migration and racism (Silvén & Björklund, 2006).

In the context of Danish OSSEIs, Paper Two mapped on-site sustainability programmes associated with biodiversity conservation, climate change, food, plastic pollution, the SDGs and technology. Nonetheless, these programmes formed only one fifth of the total mapped in the study (Evans, in press). Janes & Grattan, (2019) ask why museums have been hesitant at working with climate change in their practice, and explore ideologies behind neutrality; or *feigned neutrality* (Evans et al., 2020; Rodegher & Freeman, 2019).

In the past, zoos and aquaria placed greater emphasis on educating visitors via a facts-based approach, however in recent times a shift has taken place towards providing stories around conservation, emotion and empathy (Clayton, 2017). While visiting the Museum of Climate Change in Hong Kong, I found that a similar change in approach had taken place since opening in 2013, from a previous fact-based approach to one that is action orientated.

Although this research project is not focusing on the internal working of the OSSEIs, it should be briefly mentioned that it provides additional ways for OSSEIs to embrace sustainability, via the implementation of internal initiatives (Gill & Warrington, 2017; Hedges, 2020). For example, sustainably sourcing exhibit materials, the recycling and reusing of materials, switching to renewable sources of energy, reducing energy consumption, or as found in Paper Two - the products sold in cafes and shops. Pop & Borza, (2016) present 33 indicators for the measurement of a museum's sustainability.

2.4.1 A Growth in Museums and Exhibitions Orientating Towards Sustainability

As previously mentioned, the original project idea came from my own noticing's of new OSSEIs specialised towards sustainability (cf. Newell, 2020). These include Klimahaus Bremerhavn in Germany (2009), Museum of Climate Change in Hong Kong (2013), the Climate Museum in New York (2015), the Museum of Tomorrow in Rio de Janeiro (2015), Klimahuset in Oslo (2020) and the Museum of the Future in Dubai (February 2022). Furthermore, existing institutions were increasingly shifting their focus to sustainability, such as Museon in The Hague. Their exhibition, 'One Planet' uses the 17 SDGs as the basis for disseminating different sustainability (Museon, n.d.). Other notable mentions include the Pollution Pods designed by Michael Pinsky (see Sommer et al., 2019) and Climate Garden 2085 at the University of Zurich (Schläpfer-Miller, 2021).

In terms of Danish OSSEIs, the science centre Ecolarium opened in Vejle in August 2003, with all its exhibitions and programmes focused on sustainability (Økolariet, n.d.). The science centre Naturkraft, located in Ringkøbing, recently opened in June 2021 and calls itself a 'theme park for the powers of nature'. The institution focuses on the topics of nature, sustainability and climate (Naturkraft, n.d.).

2.4.2 Special Interest Groups for OSSEIs

The last five years have seen a growth of policy directives towards sustainability from special interest groups. In 2017, the Science Centre World Summit (SCWS) released its Tokyo Protocol to aid its member institutions in supporting the SDGs; in 2018, the International Council of Museums (ICOM) formed a Working Group on Sustainability; in 2020, the World Association of Zoos and Aquaria (WAZA) released its sustainability strategy. Furthermore, sustainability groups include Museums for Climate Action and We Are Still In.

Notable examples of professional development opportunities for staff include a handbook/guide, and workshops. Henry McGhie produced 'Museums and Sustainable Development Goals: A how-to guide for museums, galleries, the cultural sector and their partners' (McGhie, 2019), with such work contributing to museum education working towards a sustainable future (i.e. Agenda 2030) (Hansson & Öhman, 2021). Workshops for museum practitioners now exist on aspects of sustainability, such as 'Hallmarks at Home – Mobilising museums for climate action', that took place on 9th March 2022 for members of the Association of Independent Museums (AiM) (AiM, n.d.).

2.5 OSSEIs and Schools

Visits to OSSEIs by school classes are increasing in number (Gilbert & Priest, 1997). In terms of sustainability, its abstract nature and complexity creates many difficulties for schools and their teachers (Goldman, Assaraf & Shaharabani, 2013; Green & Somerville, 2015). Even though the formal education system in many cases attempts to address these difficulties, education on environmental issues in schools are often not comprehensive enough (Clayton, 2017). As highlighted in Paper Two, some schools choose to outsource this learning to OSSEIs (Goldman, Assaraf & Shaharabani, 2013). Many OSSEIs have education departments that provide contextualised learning in the form of school programmes (Hansson & Öhman, 2021). Even when financial issues lead to fewer resources being available, these institutions have increasingly had to implement 'state adopted curriculum standards', meaning education programmes remain an essential focus (Heimlich, Searles & Atkins, 2013).

In this thesis, I choose the best-case scenarios for coming across sustainability education that draws on the conditions of OSSEIs. Educator led programmes allow for greater certainty on sustainability content appearing as advertised on an institution's website. I focus on visiting school classes, due to the popular demand for school-visits to OSSEIs, and the large amount of programmes on offer. On-site school programmes play an important role in this thesis, with these formats described in the following by Heimlich, Searles & Atkins, (2013, p. 201), in terms of zoos and aquaria (attributable to all OSSEIs):

> On-site programmes are usually one-time experiences for a class. These experiences are often up to three hours in length and include lessons taught by educators at the zoo or aquarium; this staff-led lesson is the primary distinction from the field trip.

2.6 Examples of OSSEI Sustainability Practice

The final section of this chapter presents brief snapshots of OSSEI sustainability practice I have observed, which subsequently aided my research considerations on sustainability and museology.

2.6.1 Hong Kong

As expanded upon in other sections of the thesis (section 1.11.2), in autumn 2019 I carried out a 3-week research stay in Hong Kong (Figure 2 and 3).

Figure 2. Observing a Grade 4 museum tour at the Museum of Climate Change, Hong Kong. This particular image is from the Arctic exhibition, which holds collections such as sealskins, as well as a visual, sensory display of a research trip into the Arctic Circle with a Chinese icebreaker.

Figure 3. Observing a Grade 3 school programme on the human impact on ocean life at Ocean Park, Hong Kong. This image shows a puppet display communicating the effects of plastic pollution on turtles and fish, with pointers towards recycling and reusing plastic, and avoiding single use plastic whenever possible.

2.6.2 London

In autumn 2021, I visited the London Science Museum with my family to view the new exhibition 'Our Future'. The focus is on carbon capture and the different technological solutions currently available to mitigate the impacts of climate change. Shell is a sponsor of the exhibition, a relationship that has received much criticism from across society (e.g. Taylor, 2021). After a long post-visit discussion with my family, it was agreed upon that visitors leave with the unrealistic feeling of the exhibited solutions already being developed at a large enough scale to mitigate the impacts, and importantly no understanding whatsoever on the severity of the global situation. Following the visit, I contacted the London Science Museum to express my dismay at the

inaccurate dissemination approach taken in the exhibition, and the hints of greenwashing via Shell. Read more about the exhibition here: https://www.sciencemuseum.org.uk/see-and-do/our-future-planet

2.6.3 The Copenhagen area

In autumn 2021, I visited the Danish Museum of Science and Technology in Helsingør, north of Copenhagen, to view the new exhibition *Black Energy and Green Hope*. Programme Manager, Peter Bjerregaard showed me around, and this institution was subsequently chosen to represent the Danish museum community at the Final Workshop event. One exhibit shows how coal production 'saved' the Danish forests, via a graphical display of forest cover in 1800 (Figure 4) vs 1990 (Figure 5).

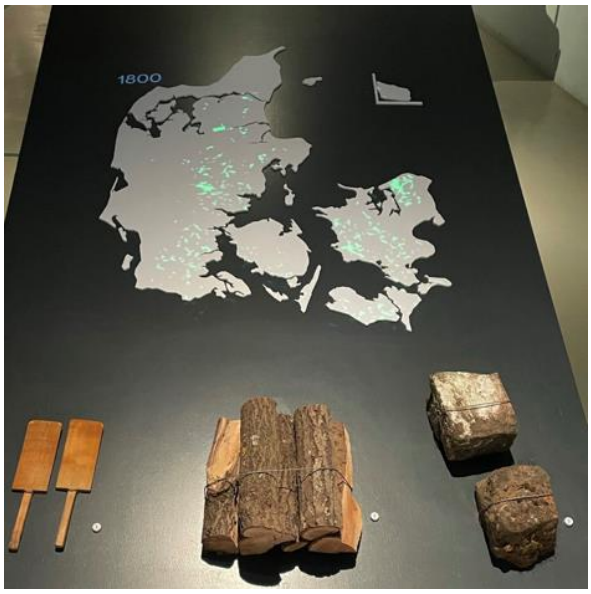

Figure 4. Danish forest cover in 1800.

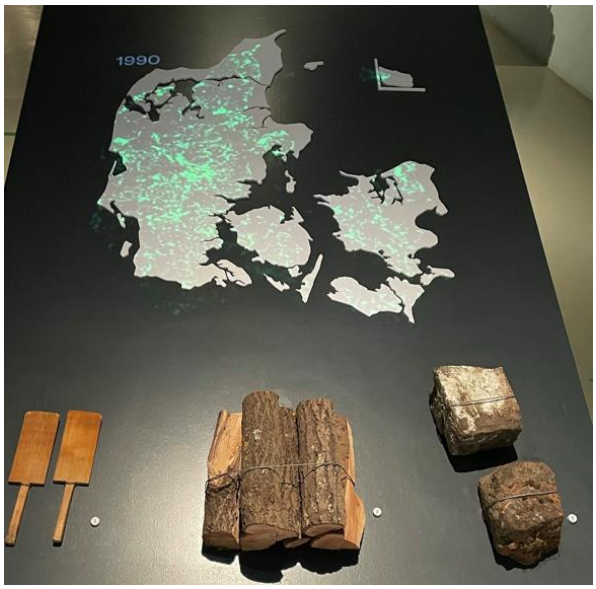

Figure 5. Danish forest cover in 1990.

In winter 2021, I visited the science centre Experimentarium in Hellerup, north of Copenhagen, with my department research group to view the new exhibition *Climate Topia – The Travellers from the Future*. This exhibition displays three different future pathways representing possible scenarios for the Earth, with each pathway communicated via a teenage girl from the future who has crash-landed (Figure 6). These scenarios are heavily based on the modelling involved in the IPCC reports. At the end of the exhibition, visitors answer a pro-environmental behaviour themed questionnaire, based on their own lifestyle choices such as meat consumption and travel. These answers combine to highlight the future pathway that your own choices are taking the Earth towards. Unfortunately, my own current actions are taking us towards an 'Orange' future – with the 'Green' pathway required for a sustainable future. A 'Red' future represents business as usual.

Figure 6. Three different future scenarios for planet Earth (red, yellow and green), represented by the three teenagers.

On the same day as the trip to Experimentarium, we also visited Kunsthal Charlottenborg in central Copenhagen to see the exhibition *The World is in You*. This particular exhibition disseminates how our bodies are connected to the world around and in us. One of the activities involved connecting different things to each other using rubber bands (Figure 7 and 8), which in turn aided the development of a potential guideline on sustainability education for 'Connectedness' (see Section 4.3.5 and Paper Three).

Figure 7. An activity using rubber bands to create connections between ideas, objects and things.

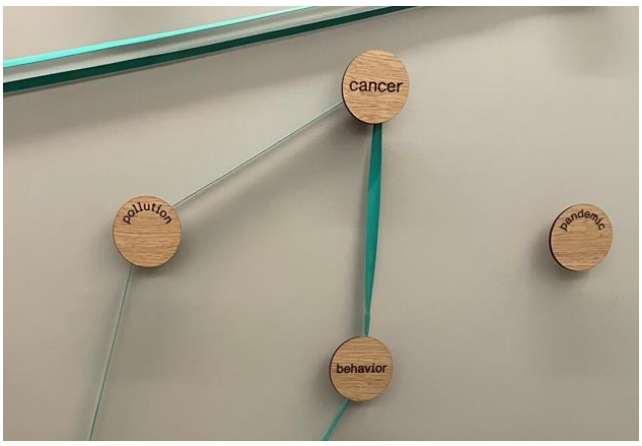

Figure 8. An example of connections made between ideas, objects and things, i.e. cancer, pollution and behaviour.

3.0 Methodology

In this chapter, I outline the general framing of the research, and discuss how the chosen paradigm has conditioned my choice of the conceptual frameworks in the individual papers that make up the body of the thesis.

3.1 Preface

This research does not use a singular theory, but instead takes different theoretical stances based on the chosen paradigm. This decision was made relatively early on in the project, because I was influenced both by my background in the natural sciences, which perhaps dictated a more quantitative approach, and my enjoyment of engaging with science education practice, which dictated a more contextual and qualitative approach.

3.2 Research Paradigms

Thomas Kuhn's book *The Structure of Scientific Revolutions* (Kuhn, 1970), is one of the most distinguished scientific publications from the 20th century (González-Márquez & Toledo, 2020) and to date cited over 137,000 times. Kuhn's personal observations of intra- and inter-disagreements in the natural and social sciences led to his formation of 'paradigms'; how scientists make sense of the world and its reality (Kuhn, 1970). Guba, (1990, p. 17) describes a paradigm as a "basic set of beliefs that guides action". Each paradigm takes a different standpoint on the philosophy of science, i.e. ontology, epistemology, methodology and methods (Scotland, 2012). Ontology involves probing into what comprises of reality (what is real?), while epistemology reflects on the ways in which knowledge formation occurs and our ways of learning about the world (how can we confirm that which is real?). Methodology takes a more practical stance on the different methods undertaken to form knowledge (how can we observe/measure/describe reality?), while methods involve the ways in which data is collected and analysed (Crotty, 1998; Kelly et al., 2018; Scotland, 2012). Denzin & Lincoln, (2011) highlight the six paradigms of constructivism, interpretivism, feminism, positivism, post-positivism and critical theory. To frame the research, the thesis uses the interpretivist paradigm.

3.3 The Interpretivist Paradigm

Over the past half a century, interpretivism has grown substantially as a research paradigm, primarily caused by the challenges that have arisen with creating scholarly knowledge through a positivist mindset (Sandberg, 2005). The striving for objective knowledge creates theoretical limitations for furthering insight into human experiences (i.e. Denzin & Lincoln, 1994). A positivist or post-positivist perspective would not necessarily seek to distinguish between the way knowledge (such as Newton's Laws) is presented in a scholarly, academic context, in a policy context, or in educational practice. In comparison, interpretivism acknowledges how

knowledge looks different in different contexts across research, policy and practice, such as within a research laboratory, a political agreement and a museum exhibit. Interpretivism takes an ontological stance in the form of relativism, which describes reality as being different for every individual. The human ability of consciousness plays a very important role. Subjectivism forms the epistemological stance, in which meaning is created between the world and human consciousness, and in social situations takes different forms for different people. An interpretivist methodology aims to understand events and experiences from an individual's point of view, by taking into account synergies between researcher and participant. Finally, methods analyse behaviour and actions through techniques such as open-ended interviews, observations and questionnaires. Criticism of the interpretivist paradigm centre on the difficulties in reaching an agreement on results, often caused by the subjectivity of reality (Crotty, 1998; Scotland, 2012; Treagust, Won & Duit, 2014).

3.4 The Out-of-School Context

Interpretivism uses the field of constructivism to describe a stance on teaching and learning. Researchers consider learning (or meaning-making) in out-of-school contexts (i.e. a museum or a zoo) as associated with visitors constructing their own understanding and meaning, as opposed to passively taking in information (Anderson & Ellenbogen, 2012). Therefore, responsibility for learning is with the learner and not the teacher. Learners have localised experiences, with these experiences dependent on factors such as culture and the context of the learning situation (Treagust, Won & Duit, 2014). This leads to the understanding of learning not being reducible to a series of quantifiable events that occur in a predictable way with controlled variables. In addition, due to the social nature of a visit to an OSSEI, research takes a broader focus than primarily focusing on the visitor.

Rennie, (2007) describes learning in out-of-school contexts as contextualised, a personal process and one that takes time. The socially constructed nature of learning means it usually involves interactions with someone or something (i.e. a museum practitioner, another visitor, an exhibit or object). Falk & Dierking, (2000) created the Contextual Model of Learning, which takes shape in the three contexts of Personal, Sociocultural and Physical. A total of twelve factors, four in each context, situate themselves across the three contexts. For example, Personal factors include motivation, prior knowledge, prior interests and choice. Learning is thus a personal process taking a different form for each individual. Within out-of-school research, it is important to capture expected and unexpected outcomes from the learner. Furthermore, learning takes time because it often involves a new context (i.e. a first time visit or new exhibition), in which people draw on previous knowledge and experiences. This can make it difficult for researchers to measure out-of-school learning, in particular within short-time events such as a one-off on-site museum or zoo education

programme for visiting school classes (Rennie, 2007). With each visitor having different backgrounds, knowledge, experiences and interests, a focus purely on interactions with an exhibition or programme does not foresee visitor learning (Anderson & Ellenbogen, 2012). As Anderson & Ellenbogen, (2012, p. 1183) write, 'it is the factors intrinsic to the visitors themselves interacting with the museum contexts that result in myriad learning processes and outcomes'. These contextualised interactions create an immense challenge for OSSEIs when attempting to analyse and provide an understanding on outcomes of practice.

3.5 The Didactic System

The Anthropological Theory of Didactics (ATD) provides a methodological approach to operationalising the broad strokes of the interpretivist paradigm, with an underlying understanding that scholarly knowledge cannot be taught in the way it was produced in the scientific community. The 'anthropological' context refers to the human nature of knowledge diffusion through society. ATD takes a sociological perspective on science education, viewing it as the diffusion of scientific knowledge, values and practices between institutions (Chevallard & Bosch, 2014); a process called 'didactic transposition'. This approach examines the deconstruction and reconstruction of knowledge for suitability within the given context (Chevallard, 2007; Chevallard & Bosch, 2014). In research institutions, scientists produce science under specific circumstances, i.e. furthering our collective knowledge of the world, while education institutions such as museums deconstruct and reconstruct this science to fit their specific circumstances, i.e. creating educational environments for learners to engage with (Achiam, Simony & Lindow, 2016; Chevallard & Bosch, 2014). ATD and the tools it has developed (e.g. Artigue & Winsløw, 2010), provide a strong and systematic framing for investigating the diversity of ways in which scholarly knowledge about sustainability is transformed into educational programmes across a range of different OSSEIs, and for considering common features across those institutions .

The notion of didactic transposition was first presented in 1975 by the French sociologist Michel Verret in 1975 (Verret, 1975), and has since diverged into the two main research fields of mathematics education and biology education. Notable figures within mathematics education include the likes of Yves Chevallard, Marianna Bosch and Carl Winsløw (i.e. Artigue & Winsløw, 2010; Chevallard & Bosch, 2014). Within didactic transposition and biology education, the likes of Jean Pierre Astolfi and Michel Develay have been instrumental (i.e. Astolfi & Develay, 1989). These research fields have developed within the context of the school environment, and also within out-of-school contexts, such as museums (i.e. Achiam, Simony & Lindow, 2016; Marandino & Mortensen, 2010). For more information, see the Conceptual Framework section in Paper One.

The majority of the science disseminated in OSSEIs originates elsewhere, with these examples of institutions 'embedded in societies', with close associations to their local communities (Bosch & Gascón, 2014). The point of departure of this thesis are the interactions between the scholar knowledge produced by researchers, the knowledge selected by societal actors, the knowledge embodied in OSSEIs , and the knowledge lived and acquired by learners. Therefore, we are interested in the 'didactic system' (see Figure 9). The reference model is constructed by the researcher as a way of analysing the suitability of the developed objects of knowledge for teaching and learning. The flow of scientific knowledge, values and practices can also proceed in the opposite direction, as indicated by the double arrows. This could be the case in e.g. citizen science initiatives, where non-scientist participants produce knowledge, test methods, and develop protocols that are ultimately employed by scientists.

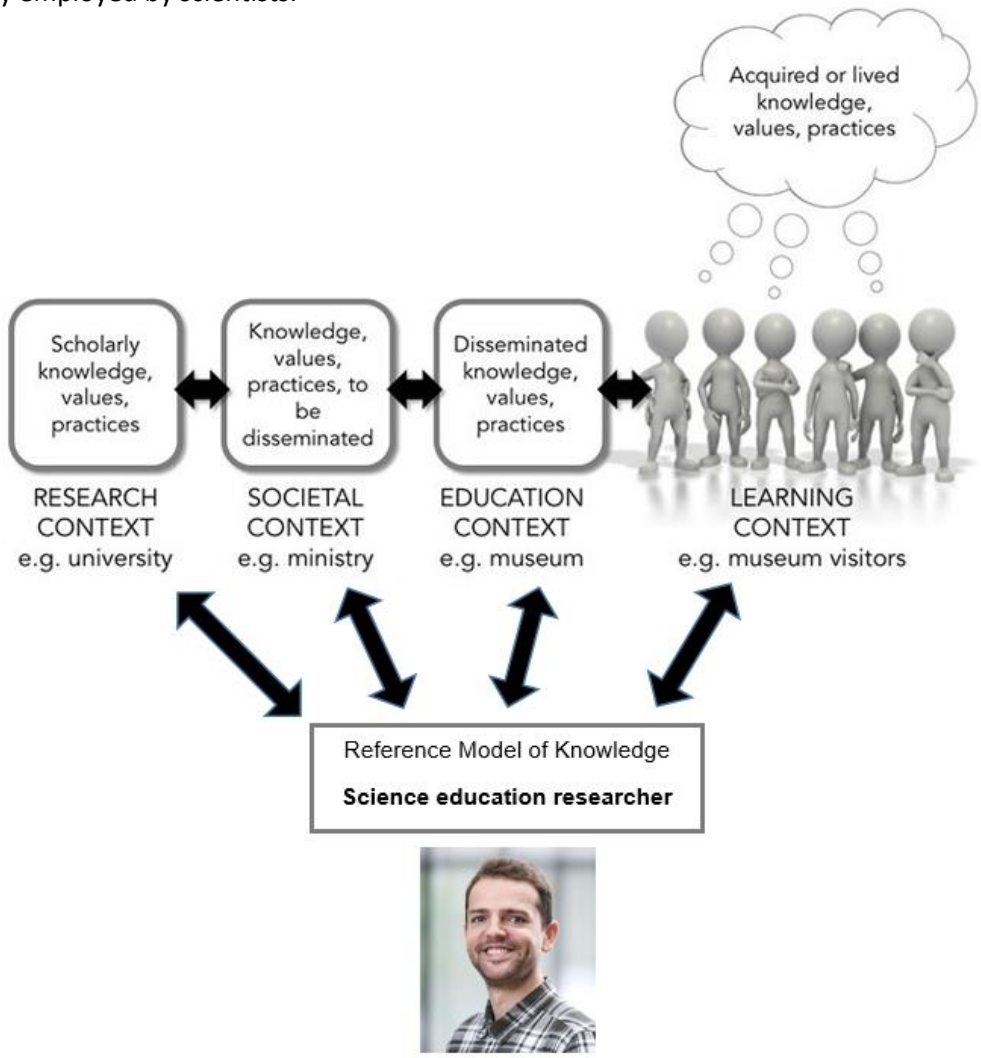

Figure 9. The process of didactic transposition, with sustainability knowledge selected and transformed, culminating in the developing of a reference model of knowledge related to sustainability, incorporating the science education researcher of Henry James Evans.

3.6 ATD and Sustainability

This research uses the tools of ATD to examine the ways in which sustainability diffuses through society and more specifically, OSSEIs. A central notion of ATD is, as mentioned, the didactic transposition of knowledge as it is sequentially deconstructed, reconstructed, taken up and again disseminated in society. The process starts with scholarly knowledge on sustainability produced by scholars in the emerging field of sustainability science, often situated within a research context. For example, Katherine Richardson is Professor of Biological Oceanography and Leader of the Sustainability Science Centre at the University of Copenhagen. Her research produces knowledge on sustainability, often in the form of research papers, such as the need for the expansion of sustainability science to achieve the SDGs (see Messerli et al., 2019). Katherine was one of fifteen scientists from around the world who worked on the 2019 UN-GSDR. This sustainability knowledge is selected and transformed by policymakers and other stakeholders in society, to form policy-directives such as the SDGs. An example from the context of out-of-school is the WAZA Sustainability Strategy, which provides directives for its members to incorporate the SDGs into their internal and external practice. This sustainability knowledge is selected and transformed by, for example educators at OSSEIs, to take the form of practice, such as a sustainability programme at Copenhagen Zoo focused on rhino conservation. The rhino specimens contribute a real-world, sensory dimension to the practice, while the SDGs operationalise the notion of sustainability to initiate discussions with students on how to improve the species' future. Finally, the learners themselves work within these interactions and conditions to form a pedagogical output (Figure 10).

Figure 10. A graphical representation of the diffusion of sustainability through society, involving a sustainability scientist (i.e. Katherine Richardson), the SDGs and WAZA Sustainability Strategy, the rhino education programme at Copenhagen Zoo, and finally the children interacting with the zoo context.

3.7 Pilot Study

In the first two months of the project, (April and May 2019), I carried out a small pilot study to further my understanding of how sustainability is transformed into OSSEI practice. This played an important role in the

early stages of project, by helping to shape research questions and providing an initial understanding of sustainability in out-of-school practice across Denmark. With the SDGs as the most up to date operationalisation of sustainability, I investigated how they are (or could be) selected and transformed into OSSEIs. The simple study provided a good opportunity to build relationships with OSSEI practitioners across Denmark; proving to be particularly useful for Paper Two and Paper Three. As outlined in previous chapters, sustainability is a vast term spanning many disciplines and structural levels. Accordingly, it quickly became clear that it would become difficult to discuss the constructive intersections between sustainability and out-of-school science education in a coherent way. Further, I became aware that not all aspects of sustainability were equally pertinent to OSSEIs. Hence, I carried out a survey to identify the aspects of sustainability most relevant to OSSEI practice. I surveyed one educator from 15 OSSEIs located across Denmark (seven zoos, three aquaria, three museums, two science centres). Exhibit and programme practitioners were identified and contacted by e-mail, with questions relating to criteria for good practice when disseminating sustainability, as well as choosing five SDGs they viewed as most important/relevant for their particular institution. The six most frequently chosen SDGs are listed in Table 1. Overall, the data collected was used in the formation of an epistemological reference model employed throughout the project.

Table 1. The Sustainable Development Goals indicated by 15 educators in Danish OSSEIs.

Sustainable Development Goal (SDG)	**Short Description**	**Number of indications by educators**
4 Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	7
7 Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all	7
12 Responsible Consumption and Production	Ensure sustainable consumption and production patterns	9
13 Climate Action	Take urgent action to combat climate change and its impacts	13
14 Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	12
15 Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	11

These SDG results helped to highlight the specific areas of sustainability deemed to be most important/relevant for OSSEI practice. The biosphere goals of 13, 14 and 15 received the most indications by both zoo/aquaria and museum/science centre practitioners. With regards to Paper One, the pilot study highlighted some initial thoughts on the unique potentials offered by OSSEIs for sustainability education. Additionally, the pilot study helped to build up an understanding of the particular areas of sustainability in school programmes to keep an eye out for in Paper Two. The pilot study results were in some way reflected in Paper Two, with the most frequent topic for sustainability programmes found being biodiversity conservation, with zoos and aquaria offering over two-thirds of the sustainability programs (see Paper Two). Ten of the 15 institutions in the pilot survey were either zoos or aquaria.

3.8 Methods

Aligning with the overarching interpretivst paradigm, I employ a range of mostly qualitative methods. Quantitative methods are used to prove or disprove, while qualitative uncover, discover, are more exploratory in nature and used to explain why quantitative results were found (i.e. Paper Two). Being a good interviewer is a skill and you can read as much theory about as you want, however one improves by getting experience. I had never done an interview before starting the PhD, and the experiences of conducting interviews in Hong Kong proved to be very valuable for Paper Two and Paper Three. The PhD course called Qualitative Methods made me aware of the often dominant nature taken by the interviewer to the interviewee, and the importance of developing a carefully thought out interview guide.

3.9 The Papers

In the four papers (see Chapter 9) that make up the body of this dissertation, I use ATD to operationalise the ideas of the interpretivist paradigm in different ways, with graphical representations highlighting their use of didactic transposition.

3.9.1 Paper One

RQ 1: What are the unique characteristics that OSSEIs offer sustainability education?

This theoretical study investigates the notion of sustainability, and the various ways it is constituted and understood in society and institutions. In addition, this research is epistemologically-focused, in that it looks at knowledge and the way it is constituted in various contexts, meaning not only were research papers, but also policy briefs and websites of special interest groups etc. Specifically, this study focuses on the implications of (these versions of) sustainability for OSSEIs and their work to create meaningful, localised experiences for learners. Using the interpretivist lens acknowledging that knowledge is always context-bound and shaped by the conditions it 'lives' within, we synthesise a model (or ecosystem) of sustainability across science, policy and practice (Figure 11), i.e. the scholarly knowledge of sustainability (sustainability science),

the dominant influential bodies in sustainability policy, and the institutional conditions of OSSEIs. The research highlights features of sustainability that are simultaneously of relevance to the institutions in question. The reference model is illustrated by using real-world examples of practice in the form of an institutionally specific reference model (Figure 9), taking into account the following types of OSSEIs: natural history museums, science and technology museums, science centres, zoos and aquaria. The paper is co-authored with Marianne Achiam, and published in *Environmental Education Research* (Evans & Achiam, 2021): https://www.tandfonline.com/doi/full/10.1080/13504622.2021.1893662

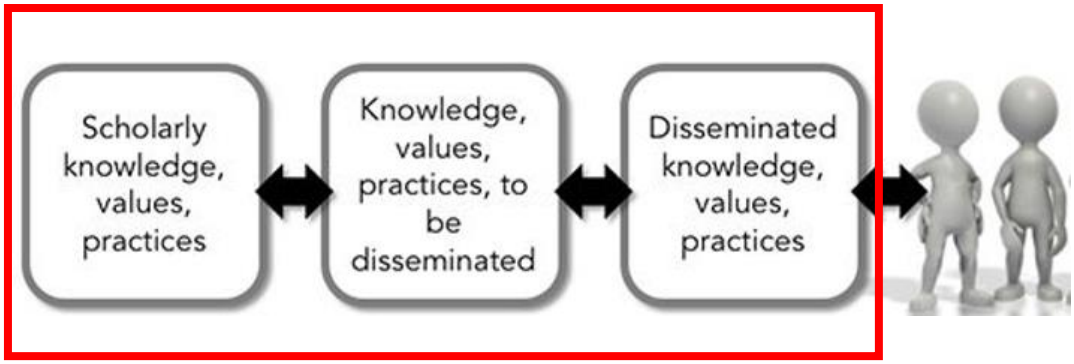

Figure 11. The didactic system involved in Paper One.

3.9.2 Paper Two

RQ 2: What is the current scope and status of sustainability education in OSSEIs located across Denmark?

This empirical mixed-methods study implicitly invokes ATD by mapping the variety of forms sustainability takes in educational programmes offered by OSSEIs across Denmark, designed for visiting school classes in grade 4-6 (age of 10-12 years old). The study investigates the different ways in which sustainability has diffused into different types of OSSEIs, i.e. natural history museums, science and technology museums, science centres, zoos and aquaria (Figure 12). The study first carries out a quantitative desktop review, followed by qualitative semi-structured interviews and observations. Finally, a deductive and inductive thematic analysis leads to the formation of themes (Braun & Clarke, 2006). The single authored paper is currently in press in *Nordic Studies in Science Education* (Evans, in press) and due for publication in the upcoming summer volume.

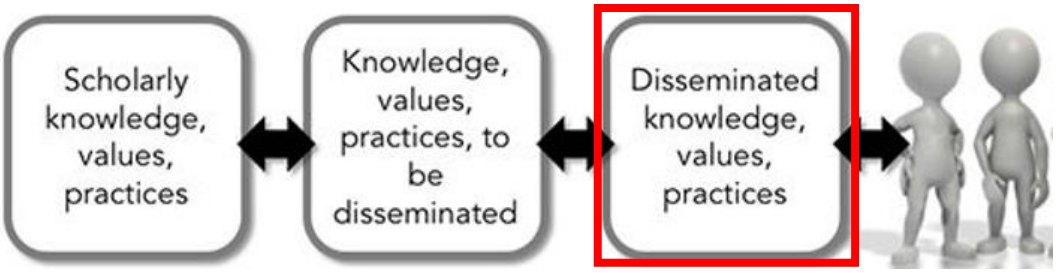

Figure 12. The didactic system involved in Paper Two.

3.9.3 Paper Three

RQ 3: What practices promote expressions of agency formation among 10-12 year old students in an out-of-school sustainability programme?

This empirical study draws on the notion of agency to investigate the diffusion of knowledge between the institutional context and the learner i.e. the interactions between an OSSEI intermediate school programme and students aged 10-12 years old. The research builds upon findings from Paper One and Paper Two to select strong candidates for sustainability practice, from which we identify good practice in OSSEIs, and how they promote expressions of sustainability agency (Figure 13). The study carries out interviews and observations, with the addition of audio recordings at specific moments. The study applies the six dimensions of environmental involvement in Blanchet-Cohen, (2008) to identify expressions of sustainability agency. We synthesise our results into a set of guidelines for sustainability education in out-of-school settings. The manuscript is co-authored with Marianne Achiam and due to be submitted for peer review to the *International Journal of Science Education, Part B* in summer 2022.

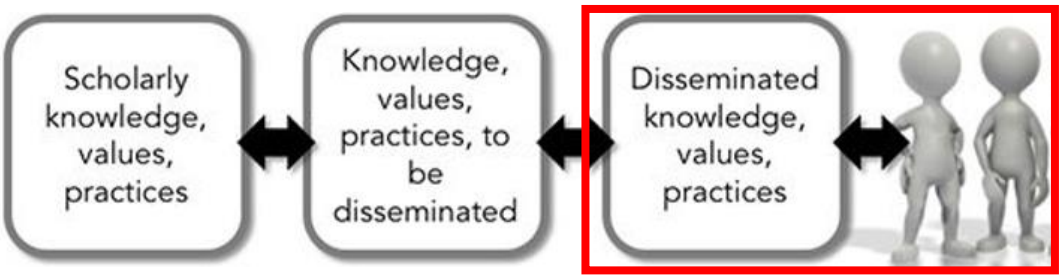

Figure 13. The domains of didactic transposition involved in Paper Three.

3.9.4 Paper Four

This position study is a spin-off type paper that fitted with the collective interest of the research group, rather than being an integral component of my thesis. Furthermore, it could be argued that the paper fits more within the critical theory paradigm, rather than the interpretivist. The paper, co-authored with Line Nicolaisen, Sara Tougaard and Marianne Achiam, is published in *The Journal of Nordic Museology* (Evans et al., 2020): https://journals.uio.no/museolog/article/view/8436

3.10 Impacts of Coronavirus

The COVID-19 pandemic severely affected data collection for Paper Two and Paper Three, due to the closure of OSSEIs, school cancellations of programmes, travel issues and departmental restrictions. This led to interviews with educators being held predominantly by phone or video software. Furthermore, when I was finally able to carry out observations of selected programmes, health precautions had to be taken, such as

maintaining distance from practitioners, teachers and students. Finally, the cancellation of conferences and reformation of those for online formats affected the dissemination of the research, and partially my development as a science education researcher.

4.0 Impact

I begin this chapter with a brief summary of the project's goals, and highlight the increasing focus on sustainability viewed within different parts of society throughout the three years. I continue by discussing the comprehensive efforts made in reaching out to Danish research and practice, and outline the project's science communication via LinkedIn. I follow this with the impacts of additional research and dissemination, before ending by discussing the project's implications for sustainability education in out-of-school settings, and providing suggestions for further research.

4.1 Project Goals

The project's funding application, sent to Novo Nordisk Foundation in autumn 2018, included impact goals for the short, middle and long term. Due to the project only just drawing to a close, it is difficult at this stage to assess goals extending beyond the duration of the project. I will briefly return to these goals towards the end of the chapter in Section 4.8.

4.1.1 Short term (during the project)

To increase awareness of the status and potential of OSSEIs for sustainability education among practitioners and researchers, achieved through the dissemination of the project's findings to researchers and practitioners via national and international conferences, visits and publications.

4.1.2 Middle term (<2 years after the project)

To transform and enhance sustainability education practices in OSSEIs across Denmark, achieved through the assimilation of the guidelines for sustainability education across a range of institutional contexts in Denmark.

4.1.3 Long term (2+ years after the project)

To motivate and empower youth to engage critically and creatively in sustainable behaviour, achieved through the widespread implementation of the guidelines for sustainability education by the out-of-school community.

4.2 An Increasing Focus on Sustainability

Throughout the duration of the project, I have noticed an increasing focus and interest on sustainability in OSSEIs. I would attribute this to a few different reasons, such as a growing societal awareness of (and concern for) global and local sustainability issues. Although impacted by the pandemic, climate strikes and environmental activism have become a regular occurrence in many parts of the world, and many political discussions focus on looking ahead to 2030 and 2050. Published reports on climate change, the biodiversity crisis and plastic pollution receive ever-greater global media coverage, and many visitors to OSSEIs will expect this to be reflected in practice. Stakeholders in society are developing sustainability plans, initiatives and

publishing reports to appeal to their customer base, with many using the SDGs as a framework. For example, see the Danfoss sustainability page here https://www.danfoss.com/en/about-danfoss/company/sustainability/ and that of Amazon's: https://sustainability.aboutamazon.com/

This section will now focus on the institutional level (e.g. OSSEIs), that of special interest groups (e.g. WAZA) and finally higher education (e.g. the University of Copenhagen).

4.2.1 Institutional Level

In the early stages of the project, I closely followed the progress of a new sustainability programme at Copenhagen Zoo for Grade 4-6 students, on rhino conservation and the SDGs. The educator, Louise Nordbjerg Bergman was very open and honest about the programme being one of trial and error, for example attempts at incorporating the SDGs into practice being completely new for the institution (Figure 14).

Figure 14. Students discussing the SDGs in terms of the poaching of rhinos, while gathered in front of the rhino enclosure at Copenhagen Zoo.

A particular example of practice within this particular programme was the visualisation of the poaching supply chain. The activity outlined the reasons for local people engaging in such illegal behaviour, with the SDGs used to prompt students in suggesting potential solutions for the problem. I held many discussions with educators at the zoo on the development of this particular programme. Over 2 and a half years later, Copenhagen Zoo now offers multiple programmes with strong sustainability content, with *Help the Chimpanzee* one example in which the SDGs play an important role in the programme. There is an activity on the supply chain of illegally chopped down wood, from source to product in shops as paper. The programme presents the Forest Stewardship Council (FSC) as a solution to the problem, which allows students to develop

an understanding of the power they hold as a consumer in choosing what type of paper to buy, as well as and how this positively impacts events up the supply food chain (see Paper Three).

Since the mapping process in Study Two, and the reopening of Danish society after the pandemic, I have noticed a number of emerging sustainability initiatives at the institutional level, with new OSSEI school programmes being developed with strong sustainability content. The relative scarcity of sustainability programmes found in Study Two cannot be put down to the pandemic, with the first desktop review taking place in February 2020 prior to the national lockdowns. However, the difficulties with finding suitable sustainability OSSEIs programmes to observe was due to the pandemic.

Paper Three provides an illustration of three sustainability programmes new for autumn 2021 at a zoo, science centre and planetarium. The chosen programme at the Planetarium, *Satellites and the SDGs* is very different to those previously offered by the institution. The educators described how their collaboration with the UN City provides the necessary sustainability expertise. An additional (and more recent example) is found at Givskud Zoo, located in Jutland, western Denmark. The sustainability programme*, The seventeen world goals and biodiversity*' is due for completion in spring 2022. The target group is school classes in Grade 3-8, with different variations of the programme to suit each grade level (Givskud Zoo, n.d.). This is the zoo's first programme orientated towards the SDGs and a clear departure away from previously identified sustainability programmes centred on the conservation of a particular species. Paper Two identified five such programmes with strong sustainability content from Givskud Zoo on the following species: the spectacled (Andean) bear, elephant, rhino, gorilla and lion. In Section 4.3.2, I discuss my keynote workshop at the Danish Association of Zoos and Aquaria (DAZA) Educators 2021 conference. An educator from Givskud Zoo, Susanne Toft Henriksen, participated in my session, and here we discussed the idea behind this future school programme. Subsequently, she was invited to the Final Workshop but unfortunately was unable to attend.

4.2.2 Special Interest Groups

In addition, I have carefully followed the increasing movement towards sustainability by OSSEI special interest groups situated at different spatial scales (see Paper One for more information). WAZA presented their Sustainability Strategy, titled 'Protecting our Planet', at their online conference in autumn 2020, which provides external and internal directives to their members based on the SDGs. As part of the second 2021 issue of the WAZA News Magazine, I wrote a three page popular science article, titled 'Operationalising Sustainability in Zoos and Aquaria' (Evans, 2021); based on Paper One. Turning to the national level, the DAZA Educators 2021 conference had a complete focus on sustainability, and all educators attending presented brief examples of sustainability practice at their institution.

The International Council of Museums (ICOM) are a large interest group and big player in museum policy. They have an ongoing consultation over changing the official definition of a museum, to one more reflective of present day society. To date there are five definition proposals on the table, featuring terms such as 'inclusive' and 'sustainability' (ICOM, 2022). In November 2021, I presented online as a keynote speaker at the ICOM International Symposium on Museums and Sustainability, located in Hangzhou, China (Figure 15).

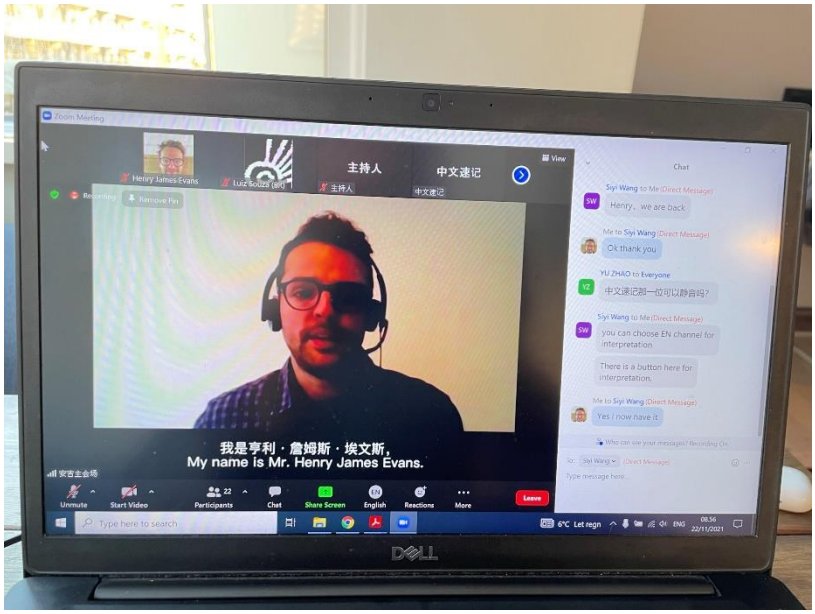

Figure 15. Presenting the project online at the ICOM Museums and Sustainability conference in Hangzhou, China.

4.2.3 University of Copenhagen

In the earlier section of 2.2, I discuss the growing research domain of sustainability science. Due to this expanding domain, the broad nature of sustainability problems and call for interdisciplinary thinking, one would expect sustainability to be an important point on the agenda of research and teaching across the University of Copenhagen. In autumn 2019, the Sustainability Science Centre compiled a mapping of courses using the SDGs as a framework. Read more here: https://sustainability.ku.dk/studies/study-sustainability/

In spring 2020, the Department of Science Education formed a Sustainability Steering Group, with the aim of encouraging greater incorporation of sustainability into teaching courses. I played an important role at the beginning of the group and engaged in discussions with assistant, associate and full professors. In 2020 and 2021, I carried out a 3-hour lecture titled 'Sustainability and Science Communication' to students on the summer course, Science Communication in Theory and Practice.

4.3 Reaching Out To Danish Research and Practice

Over the past three years, I've gone to great lengths in reaching out to Danish practice. At times language has been very challenging, but for the majority I've managed to overcome this with a combination of hard-work and persistence, and perhaps most importantly of all - patience from the educators. I've used a variety of mediums, such as visiting and presenting at OSSEIs, conference participation, publishing articles in specialised magazines, professional development and the Final Workshop event.

4.3.1 OSSEIs

Across the three years, I've carried out visits to eleven different OSSEIs across Denmark to represent the project. Below I provide a list by geographical region:

- Jutland (western Denmark), three OSSEIs = Aalborg Zoo, Ecolarium, Kattegatcentret, Ree Park Safari
- Fyn (central Denmark), one OSSEI = Odense Zoo
- Zealand (eastern Denmark), seven OSSEIs = Copenhagen Zoo, Danish Museum of Science and Technology, Experimentarium, Natural History Museum Denmark, Planetarium, The Blue Planet, Øresund Aquarium

In November 2019, I presented the project at the annual Copenhagen Zoo seminar (Figure 16), and was the only presenter on education. Furthermore, in the past 5 years, this particular institution had published no papers in the education domain, which indicated an opportunity in itself. Copenhagen Zoo have asked me to present the guidelines from Paper Three to their education team on Wednesday 20th April 2022.

Figure 16. Presenting the project at Copenhagen Zoo in November 2019.

4.3.2 Conferences

Big Bang (https://bigbangkonferencen.dk/)

On behalf of the project, in April 2021 Marianne Achiam presented the results from Paper One at the Danish educational conference called Big Bang. I took a co-leading role in preparing the session, and organised the panel of Anne Vibeke Kragelund, School Consultant from Ecolarium and Louise Nordbjerg Bergman, Head of Dissemination and Teaching from Copenhagen Zoo.

DAZA Educators Conference

On the 28th and 29th October 2021, I attended the DAZA Educators Conference at Ree Park Safari in western Denmark. 19 educators from nine different zoos and aquaria across Denmark attended the conference. I presented my keynote workshop on the morning of day two and included many activities, such as group discussions and the use of Menti (Figure 17).

08:00-09:00	**Morgenmad i jeres Cabins**	
09:00-10:30	**Sustainability Education in Out-of-School Settings and Group activity**	Henry James Evans
10:30-11:00	**Break/luftepause/Walking Safari i den nye fuglevoliere/Togtur med Amerika Expressen**	

Figure 17. My keynote at DAZA 2021.

4.3.3 Danske Museer

As a spin off article from Evans et al., (2020), my research group published an article adapted for Danish audiences in the specialized magazine, *Danske Museer* (Tougaard et al., 2021).

4.3.4 Novo Nordisk Foundation

On the 15th October 2021, I carried out a one-hour professional development workshop to the Education & Outreach Team at Novo Nordisk Foundation. Eight people participated, including Senior Project Manager, Maj Leth-Espensen and Project Manager, Thomas Dyreborg Andersen. I met Thomas and Maj once again on the 3rd February 2022 for an informal meeting on sustainability education, as well as to hear about the ongoing development of the foundation's sustainability plan. Finally, they both participated in the recent Final Workshop event.

4.3.5 Final Workshop

The project's final dissemination activity took place on the Friday 25th March 2022 from 09:00 to 15:00 at the Department of Science Education, University of Copenhagen. Planning for the event began over six months previously, and in early December 2021 educators from OSSEIs across Denmark received invitations to attend

(Appendix A1, A2). Based on the selection of strong candidates for effective sustainability education in Study Three, three invited educators presented throughout the day: Ditte Sofie Andersen from Copenhagen Zoo, Sabrina Louise Rand from Ecolarium and Birgitta Præstholm from Denmark Museum of Science and Technology. I had observed Ditte as the educator teaching the school programme *Help the Chimpanzee*, and the same for Sabrina with *The World is Warming Up*. I felt it was important to have a museum representative, and so Birgitta was chosen based on their new exhibition, *Black Energy and Green Hope*. Ditte, Sabrina and Birgitta received the guidelines two-weeks before the event, with these including examples of reflective practice in their institutions and particular school programme. In addition, I held a one-hour Zoom meeting with each presenter to help prepare their presentations, and discuss the guidelines in relation to their institutional practice. The title of the event was 'Inspiration and guidelines for the design of teaching activities on sustainability', with the day centred on results from Paper Three (Figure 18).

Figure 18. Marianne and I introducing the Final Workshop.

After a brief welcome, Marianne presented a short introduction on wicked problems, based on her recently published volume*, '*Addressing wicked problems through science education: The role of out-of-school experiences' (Achiam, Dillon & Glackin, 2021). Afterwards, I presented a synopsis of the project's aims and results, followed by an introduction to the guidelines (Figure 19, 20). Next, the three educators presented their 3-4 chosen guidelines in relation to their practice. The guidelines were provided for the participants in the form of a handout in table form, in a way that operationalised them for planning teaching courses, and examples of what this could look like in out-of-school practice. I presented the guidelines in Danish, with these since translated into English (Appendix B1, B2).

Figure 19. Guidelines in Danish.

Figure 20. Guidelines in English.

During the breaks, participants were able to gather around tables set up by the three presenters, with activities highlighting their sustainability education practice (Figure 21). For lunch, a local company called Foodoir served a sustainable menu (Figure 22).

Figure 21. Birgitta, Sabrina and Ditte presenting activities associated with their programme to workshop participants.

Figure 22. The Foodoir chef presenting the sustainable lunch menu.

After lunch, participants divided into three groups to discuss seven set questions (Figure 23, 24).

Figure 23. A group discussing questions on the guidelines.

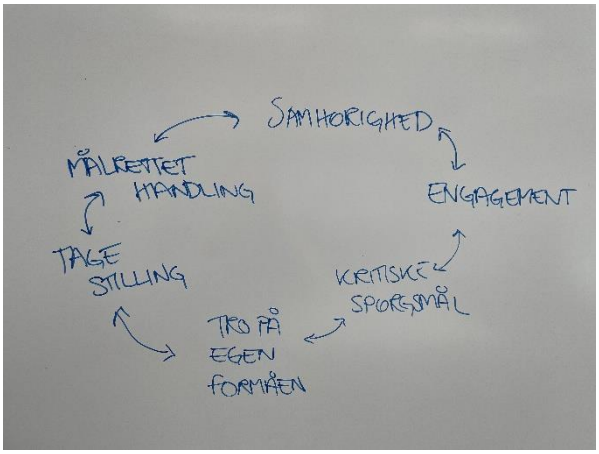

Figure 24. One participant conceptualised the guidelines in a different way to that presented (written in Danish).

See Appendix C for the full set of seven questions. Following the group discussions, everyone gathered again and Marianne led a sharing of group discussions – focusing on two of the seven questions in particular (bold, Appendix C). See below:

Question A: *Choose three guidelines that best suit the teaching and dissemination practice you have, and why?*

Answer: Marianne and I collected results in quantitative form by asking for a hands-up when going through each guideline (Table 4)

Table 4. The participants responses to Question A.

SDGs	Connectedness	Engagement	Critical questions	Self belief	Take a position	Targeted action
0	8	8	3	6	0	4

The three guidelines most commonly chosen by participants were connectedness, engagement and self-belief.

Question B: *Will these guidelines be able to help you the next time you plan a programme that focuses on sustainability? If so - in which way?*

Overall, participants felt the guidelines were a good checklist for future work and useful in many different contexts. Additional comments were self-belief, take a position and targeted action are all very similar, and that 'time' and 'extending the experience' were potentially missing components. Finally, Menti provided a platform for a brief evaluation of the day, and these comments will be collated over the coming weeks and months. I view the Final Workshop as the first 'test event' for the guidelines.

4.4 Science Communication

This section links strongly to the previous one, with Danish practice an important focus of the project's science communication efforts. In addition, all communication was also translated into English and sent out via personal channels.

4.4.1 Paper One

In March 2021, the publication of Paper One was announced on my personal LinkedIn via a short summary of 75 words and 7 emoji's (Figure 25). One year later, the post has received 2,686 views, 73 reactions and 15 comments.

Delighted to share my first published PhD paper with the world! 😀 We are all familiar with the term 'sustainability' ♻ and are aware that education plays a major role in moving towards a greener future. However, what does sustainability actually look like in science education in museums 🏛, science centres 🔬, zoos and aquaria 🐠? We give concrete suggestions from a perspective of research, policy and practice. We hope our work will inspire you to engage further in facing some of the greatest global challenges 💥

Figure 25. The short summary of the published paper posted on my own LinkedIn profile.

4.4.2 Paper Two

In January 2022, the acceptance of Paper Two for publishing was announced on our research group Science Communication page via a 1-minute 34-second long graphical animation (Figure 26). To date it has received 1,163 views and 47 reactions.

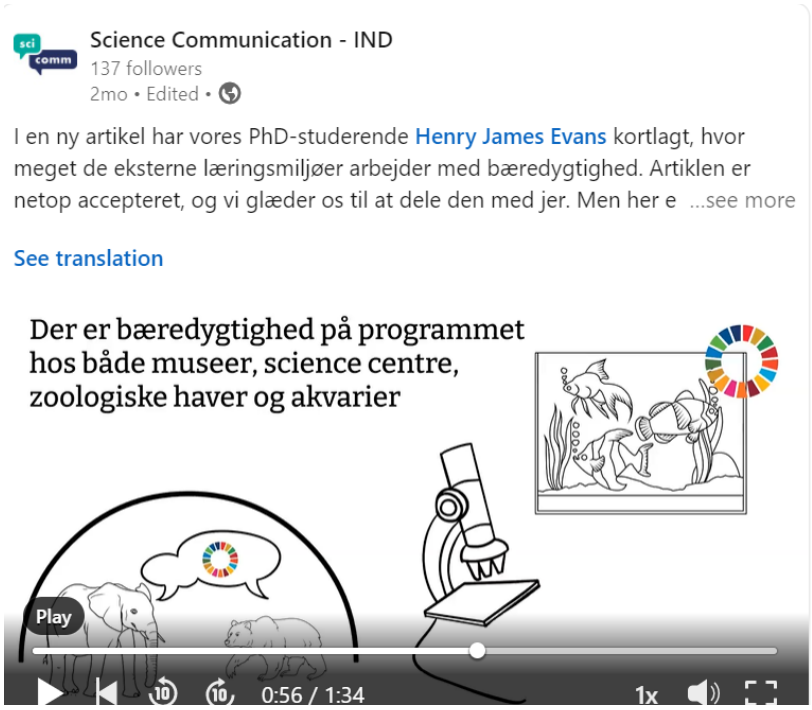

Figure 26. The post and graphical animation of Paper Two (in Danish).

4.4.3 Project Summary

In December 2021, a summary of the project was posted on our research group Science Communication LinkedIn page via a 42-second long video (Figure 27). After sharing the video onto my personal page, to date it has received 56 reactions in total across both accounts.

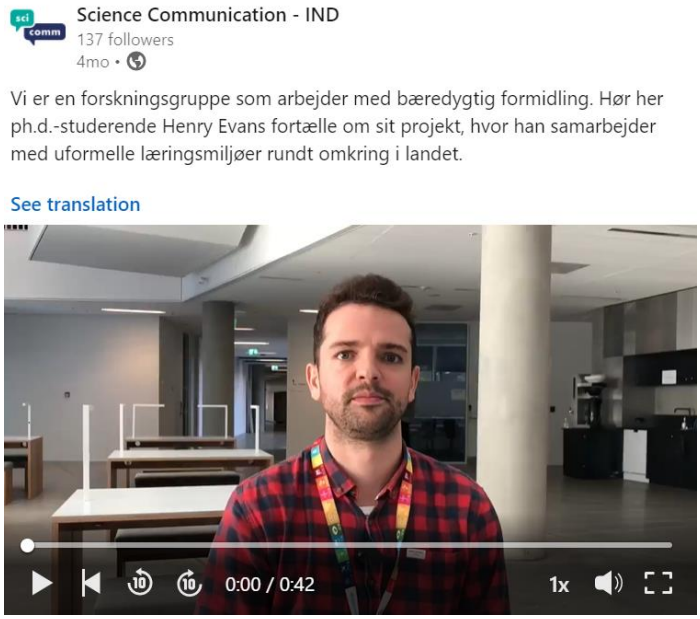

Figure 27. The post and video of the project summary (post in Danish, video in English).

4.4.4 Final Workshop

On the morning of the Final Workshop, a post with a description and photos was uploaded on our research group Science Communication LinkedIn page (Figure 28). 24 hours later at the time of writing, it has received 32 reactions.

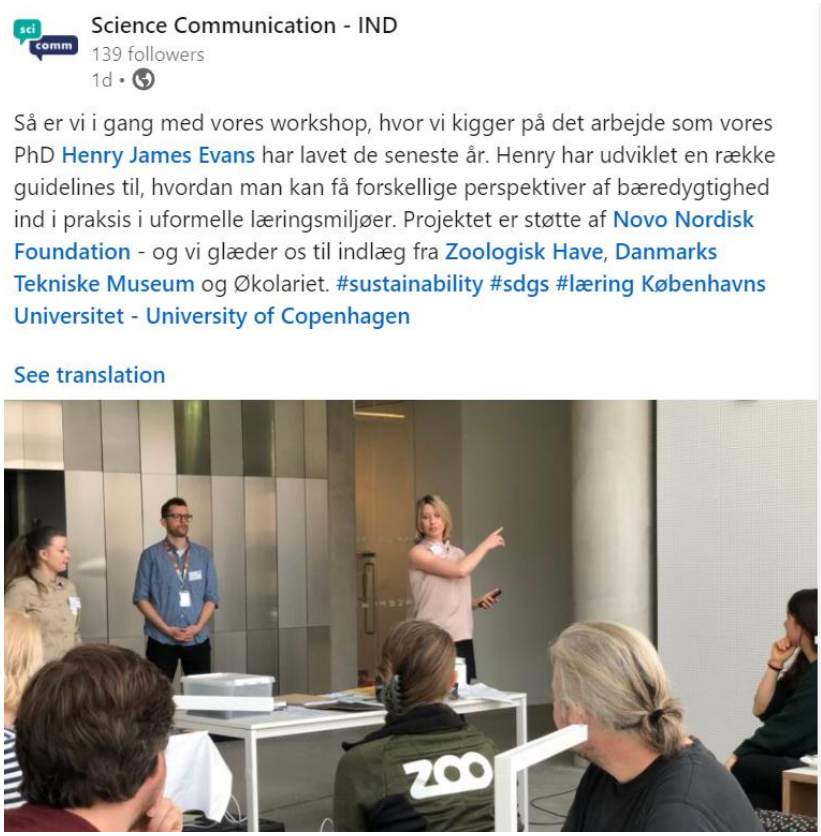

Figure 28. The post and photos of the Final Workshop (in Danish).

4.5 Research

Two research papers have been published in respected journals, one is in press and another is to be sent for review after the project deadline in late spring or early summer 2022. Paper One was published on the 6th March 2021 in the BFI 2 international journal, *Environmental Education Research*. To date it has been cited six times, such as by Iannini & Pedretti, (2022). Paper Four was published on the 21st December 2020 in the BFI 2 Nordic journal, *The Journal Nordic Museology*. To date, it has been cited four times, such as by Piqueras et al., (2022).

4.6 Other Dissemination

4.6.1 Conferences

I attended the Ecsite 2019 pre- and main conference in early June 2019, hosted by Experimentarium just north of Copenhagen. In late June 2019, I attended the Klimahaus Bremerhavn Symposium on climate change. The following year, I carried out my first conference presentation at the next Klimahaus Bremerhavn Symposium, based on Paper One. I had two abstract presentations accepted for the EERA 2020 conference in Glasgow, August 2020, however cancelled due to the pandemic (no online version created). I attended the 2020 ESERA Summer School and attended seminars and workshops. In addition, I presented the project to my group of students and two academics, and receiving detailed and very useful feedback. The lead academic in my group, Costas Constantinou from the University of Cyprus, felt that my project was very unique due to its analysis across research, policy and practice. In September 2021, I attended the ESERA conference and participated in Strand 9 titled **'**Environmental, Health and Outdoor Science Education'. The following week, I attended and presented Paper One at ECER 2021, participating in Network 30 titled 'Environmental & Sustainability Education Research'. Finally, Marianne and I had a co-authored abstract accepted for the ECSITE 2021 conference in June 2021. Similar to the previously mentioned Danish conference called Big Bang, Marianne presented on behalf of the project and I took a leading role in finding suitable panel speakers, which included Justin Dillon as chair, Henrike Welpinghus from Klimahaus Bremerhavn and Yuri Matteman from Naturalis.

4.6.2 Kings College London

As part of my two-month research stay at Kings College London in spring 2021, I carried out a one-hour online presentation and discussion of the project to the Centre for Research in Education in Science, Technology, Engineering and Mathematics (CRESTEM - a research group). Thirty people attended including Professor Michael Reiss and Dr Sue Tunnicliffe from University College London. Through contacts at King College, I joined UK-based networks in sustainability education, such as the 'Environmental Education PhD' group -

formed of PhD students across the UK, and the 'Environmental and Sustainability Education' group - formed of academics across the UK. I also joined the London Environmental Education Forum.

4.6.3 Henry McGhie

One of the first people I came across in museums and sustainability literature was Henry McGhie, a consultant and former museum curator at the Manchester Museum. Over the last couple of years, he has developed into a big player in museum policy moving towards embracing the SDGs, such as through his free guide for museums and presenting at ICOM conferences. On the 14th June 2019, I had a Zoom meeting with him to discuss the world of sustainability education in out-of-school settings. Henry provided me with some useful directives and sources of information.

4.7 Help the Chimpanzee – An Example of Good Sustainability Practice

The Copenhagen Zoo programme, *Help the Chimpanzee* is by far the most 'effective' example of sustainability practice I've come across during the project, in terms of institutional fit, strength of sustainability content, pedagogy, inclusion etc. This list of achieved 'researcher criteria' justifies the important role the programme played in Paper Three and the Final Workshop. The programme points to many features of sustainability science and policy identified in Paper One, such as working across multiple spatial scales and providing a historical consciousness. Furthermore, the interdisciplinary focus of mathematics, biodiversity conservation and genetics fits with the features of sustainability science, and maths teachers, researchers and educators all played important roles in programme development. In addition, the Danish science education consultancy, NEUC, helped to develop the programme. They are carrying out a formative evaluation via both observations by researchers and data collection by students.

The programme is free for full schools to attend and so sold out very quickly, due to receiving full external funding by Novo Nordisk Foundation. Previous zoo research on populations of chimpanzees and genetics form the backbone of the programme, adding to the conditions of the zoo playing a critical role in the activities. The duration of 3.5-4 hours provides an extended experience for the school classes, and allows for a variety of different activities and learning objectives. A mixture of zoo classroom, chimpanzee enclosure and exploring the zoo maintains the focus of students. The programme induces science identity through the roles of either a field biologist or a scientist, with both professions working together to solve a task – another pointer towards sustainability and interdisciplinary methodologies. The use of chimpanzee poo and Lego also ensures an experiential and fun session for the students. Finally, the programme initiates the senses, whether by smelling, seeing and listening to the chimpanzees in their enclosure, or the use of sound effects in the zoo classroom.

Paper Three outlines where and how this particular programme fits with the guidelines, and the particular practices that lead to expressions of agency by students.

4.8 Returning to the Project Goals

I believe that the short-term goals have been achieved, with research and dissemination efforts increasing awareness of the status and potential of OSSEIs for sustainability education among practitioners and researchers. On the middle-term, the hope is that the Final Workshop will be the start of the assimilation of the guidelines for sustainability education across a range of institutional contexts in Denmark. Institutional visits, conferences, science communication and research outputs will further these aims. Ultimately, this would lead to the long-term goal of motivating and empowering youth to engage critically and creatively in sustainable behaviour.

4.9 Implications

Sustainability is a global conversation now firmly situated at the top of the agenda across research, policy and practice. The domain of sustainability science continues to advance in number and depth, political circles regularly discuss the future of humanity, funding circles increasingly turn their attention to the green transition and citizens are waking up to the levels of change needed for a global transformation. Since starting in 2019, the project has been at the front of a sustainability wave, and momentum is only set to multiply as we move closer to 2030 – the target for reaching the ambitious targets forming the SDGs. Education plays an essential role in creating a more sustainable and inclusive future (e.g. Holfelder, 2019), and OSSEIs offer a whole host of unique conditions and expertise for sustainability education (e.g. Clayton, 2017; Evans & Achiam, 2021; Janes & Grattan, 2019).

Study One builds on existing evidence of the difficulties faced by OSSEIs in incorporating sustainability into practice (Brown, 2019; Cameron et al., 2013; Hedges, 2020) and provides new insights into the optimal organisations of sustainability in different types of OSSEIs. The research presents preliminary criteria for good practices that may be of interest for out-of-school practitioners working in, or intending to work in the realms of sustainability practice. The institutionally specific reference model allows for more concrete suggestions and illustrations. These findings, as well as those from Paper Three, may contribute to the analysis of existing sustainability practices (i.e. Iannini & Pedretti, 2022), as a framework for emerging ones and sparks of inspiration for future initiatives .

Study Two contributes a clearer understanding on the landscape of sustainability education across Denmark, such as where and how it is taking place. The research identifies zoos and aquaria as the instigator of the majority of sustainability programmes for early adolescents, presenting an interesting dilemma on if, and where the notion of sustainability is an easier fit for their practice. Somewhat reflective of these findings,

and as highlighted in the thesis, the special interest groups of WAZA and DAZA have placed much focus on sustainability over the past couple of years. The ongoing disputes within museum practice and ICOM over a new definition, described by Adams, (2021) as one between 'reformers' and conservatives', suggests an identity crisis within this particular out-of-school field. A total of five sustainability programmes identified across four Danish museums hardly suggests a wave of momentum towards the topic, particularly when taking into account a further three Danish museums offering no sustainability programmes at all. We hope that our institutionally specific illustrations of sustainability practice in natural history museums and science and technology museums may in some way positively contribute, as well as our guidelines for sustainability education from Paper Three.

Turning to science centres, the finding of six sustainability programmes across the entire country, and all coming from a single institution that places sustainability at the forefront in everything it does (Ecolarium), creates similar questions to those for museums. However, since the mapping was carried out, some notable sustainability examples have appeared in science centres, such as the exhibition and corresponding teacher-led programme, *Climate Topia - The Travellers from the Future* at Experimentarium (see Section 2.6.3), as well as the new sustainability focused institution in western Denmark, Naturkraft.

To end the discussion on Study Two, I'll mention the strong influence that schools have on the development of sustainability programmes in OSSEIs across Denmark (cf. Insulander & Öhman, 2021). A similar finding appeared at the Museum of Climate Change (see Section 6.6.1), suggesting a more global than national influence. Ensuring their offerings appeal to teachers and incorporate elements of the school curriculum present a dilemma for OSSEIs, and may limit the ability to draw on their unique expertise and conditions. Financial issues (cf. Heimlich, Searles & Atkins, 2013), multiplied by the need to close during the pandemic, possibly come into play here too, with the need to attract schools to raise much needed income and support the existence of the education teams.

As highlighted by the programme *Help the Chimp*anzee, selected in Paper Three as a strong candidate for effective sustainability practice, external funding can provide excellent opportunities for sustainability education. However, as discussed in Paper Four with *feigned neutrality*, and illustrated via the London Science Museum exhibit sponsored by the multinational oil and gas company, Shell (see Section 2.6.2), external funding can also bring many limitations and challenges. These include accusations of greenwashing, and resignations from the museum's advisory board over the relationship (Carrington, 2021). In response, the director of the institution defends the sponsorship, and argues that it is better to include fossil companies in the discussion. Returning once again to the Museum of Climate Change, they explained their recent change in dissemination strategy, from a facts-based (and more neutral) approach, to one strongly action-orientated.

To identify and describe good practice, Study Three incorporates the findings on institutional characteristics from Study One, and the mapping of sustainability education from Study Two – to formulate guidelines for sustainability education in out-of-school practice. These resulting guidelines could be of use when institutions develop sustainability programmes, to ensure effective dissemination efforts that develop agency and provide hope for visitors. The Final Workshop was a useful first test event for the guidelines, and highlighted their potential in helping educators grapple with the fuzziness and complexity of sustainability.

Taking into account the process of this thesis, below is a brief six-step plan (A-F) for out-of-school educators perhaps interested in engaging with sustainability practice:

A) Outline what the notion of sustainability means to you and list associated topics.
B) Discuss the specific personal and professional reasons for having interests in developing sustainability practice.
C) Brainstorm the challenges faced (or possibly faced) when working with sustainability in out-of-school science education.
D) Outline the specific institutional expertise and conditions available to you.
E) Map out the current existing institutional external and internal practice, and consider where and how sustainability orientated teaching and learning already appears - and where it could in future.
F) Attempt to design a sustainability programme using the six guidelines (see below) as prompts for inspiration and direction.

4.9.1 Guidelines for Sustainability Education

Below are the six guidelines for sustainability education in out-of-school settings, with examples of good practice.

1. *Allow/help children to connect with, notice, observe and immerse themselves in their physical surroundings, for instance via an animal enclosure, a kinaesthetic exhibition or a cinematic dome.*

2. *Allow/give children time and opportunity to discover and interact with their surroundings, for instance by using objects, interacting with exhibits and developing products/ideas.*

3. *Allow/help children to (dare) ask their own critical questions, to discover the complexity of the problems and the conditions that hinder action towards sustainability challenges, for instance illegal deforestation, unequal distribution of resources and population growth.*

4. *Frame sustainability problems in a positive or constructive way that gives the children hope by pointing to concrete and realistic solutions to the sustainability problems, for instance highlighting global and local cooperation, collaborating and providing materials to take home.*

5. *Make sure that the teaching process helps the children to define and qualify their own approach to acting on sustainability issues, for instance via providing actionable knowledge and recreating supply chains.*

6. *Use the Sustainable Development Goals actively, by showing concrete connections between the goals and children's everyday life.*

My final comments for this section focus on recognising the importance of trying - trying to tackle the unwieldy nature of sustainability, and being open about any imperfections. Regarding internal sustainability at the Natural History Museum London, they state on their website the following:

> We aren't perfect, but we're looking at ways we can reduce the Museum's carbon emissions and energy consumption, reuse and repurpose technology, and encourage everyone to refill and recycle (Natural History Museum, n.d.).

Visitor's wants to see progress towards a more sustainable future, but when facing institutional, educational honesty and integrity – they will undoubtedly support efforts; a challenge that OSSEIs should fully embrace through external and internal initiatives as we head closer to 2030 and beyond.

4.10 Future Research

With the field of sustainability education growing in scale and importance, and the sheer number of different elements that make up this particular thesis, the project findings naturally lead to further research questions. To expand the uses of preliminary criteria for good practice, Study One could be expanded to include illustrations of institutional fit with sustainability in botanical gardens (i.e. Sellmann & Bogner, 2013; Zelenika et al., 2018), planetariums (Achiam, Nicolaisen & Ibsen, 2019; Nicolaisen & Achiam, 2020) and art and history institutions (e.g. Crossick & Kaszynska, 2016; Heinrichs, 2018).

An updated mapping of sustainability education in out-of-school settings across Denmark, post-pandemic, would provide an understanding of a potentially changing scope and status – more representative of the societal worry on the future of humanity. In addition, the mapping could focus on different age-ranges, such as lower school (Grade 1-3, 'indskoling) and upper school (Grade 7-10, 'udskoling'). Is there a similar relative

scarcity of sustainability programmes, and do zoos and aquaria once again provide the majority of the programmes?

The Final Workshop highlighted the potential for future engagement with stakeholders on the guidelines, such as in contexts of research, policy and practice, and their uses in developing new sustainability programmes in out-of-school settings. The preparation and release of an easily readable and accessible guide for educators, as well as publishing Paper Three and the guidelines, are both post-PhD priorities, dependent on funding and stakeholder interest. The questions provided at the Final Workshop show my thinking in other potential research questions (see Appendix C). It could also be interesting to carry out research in and with a world-renowned out-of-school institution with strong orientations towards sustainability, such as the Natural History Museum London, to see how the guidelines fit with their practice. See https://www.nhm.ac.uk/discover/sustainability.html to learn more. Turning attentions towards agency, non-human agency is an additional important component in the context of sustainability (Contesse et al., 2021; Hensel, 2019; Teerikangas et al., 2021), and so could provide an interesting context for further study in out-of-school sustainability practice.

5.0 Conclusion

The aims of the thesis were threefold; to operationalise the notion of sustainability in ways more meaningful for the education missions of out-of-school settings; to map the landscape of out-of-school sustainability education in Denmark, and through the identification of good practices – produce a set of guidelines for sustainability education in out-of-school settings.

Study One/Paper One found the notion of sustainability to look very different across sustainability science, policy and practice, and as illustrated through an institutionally specific reference model - OSSEIs offer a whole host of unique potentials for engaging in sustainability education. These include the ability to transcend disciplinary boundaries, becoming inclusive and accessible, hubs for dialogue and debate, offer different modes of communication, work at multiple spatial scales and hold a historical consciousness.

Study Two/Paper Two found a relative scarcity of out-of-school sustainability programmes in Denmark, with the majority offered by zoos and aquaria. The strong foundation of sustainability within Denmark is not filtering into out-of-school science education, perhaps caused by the fuzziness and complexity of the concept. Furthermore, the formal education sector, i.e. teachers and curricula, play an influential role in the development of the programmes - a situation that may be limiting the out-of-school community in fully optimising their unique conditions and expertise.

Study Three/Paper Three built on Study One and Study Two to select three strong candidates for effective strong sustainability education in a zoo, science centre and planetarium; *Help the Chimpanzee*, *The World is Warming Up*, *Satellites and the Sustainable Development Goals*. To describe good practice, I applied the framework of environmental involvement in Blanchet-Cohen, (2008) to develop themes illustrating expressions of sustainability agency among children. Findings confirmed the presence of five out of six dimensions forming the framework, meaning I found five corresponding themes in the data set. Furthermore, I inductively found an additional theme - the SDGs. I synthesised the results into a set of guidelines for sustainability education in out-of-school settings, and engaged stakeholders in employing these guidelines through a Final Workshop event.

Paper Four explored the issue of *feigned neutrality* in the context of museums, and provided greater understanding on the importance of inclusion in out-of-school practice.

5.1 The Project's Successes

I view the project's successes as being the publishing of research in reputable international and Nordic journals, the wide range of dissemination activities undertaken with both Danish and international research

and practice, and finally the science communication efforts. Having my first paper accepted for publication was a moment of pure joy – I was to be a published researcher! Science communication is a strong passion of mine, and it soon became a priority to engage with society whenever possible. The Final Workshop was an excellent day, and participants seemed interested and enthusiastic about the guidelines presented to them. This project on sustainability education has many unique elements to it and I'm very proud of the overall output achieved.

5.2 The Project's Shortcomings

I view the project's shortcomings as being the major interruptions to data collection caused by the COVID-19 pandemic, which has led to the need for flexibility, patience and even greater amounts of hard work than initially anticipated. In addition, the project has received some comments on the lack of focus on planetariums and botanical gardens in Paper One. Furthermore, my inexperience with social science, science education research and qualitative data has been a hindrance at times. On many an occasion I found myself in seminars, conference sessions and discussions with colleagues on theorists such as Dewey or Vygotsky, or the interpretivist and critical theorist paradigms – with hardly a clue of what was going on. In response, the project has taken a more pragmatic response to science education; not using a singular theory, but instead taking different theoretical stances based on the chosen paradigm. It wasn't until at least halfway into the project that I could feel myself finally breaking away from the positivist researcher I had previously been. Overall, the project reflects my own self as a science education researcher – one now with experience in both the natural and social sciences.

5.3 Final Comments

The past three years have been such a rollercoaster; a continuous journey of learning. Throughout, I've felt that in my own small way, I've been working towards achieving a more sustainable, inclusive future for us all on planet Earth - a goal in life potentially difficult to beat. I am excited for what the future may bring.

6.0 Additional Information

This chapter contains a list of additional information associated with my three years as a PhD fellow at the Department of Science Education, University of Copenhagen.

6.1 Written Work

I have written or contributed to seven articles in both research and popular science; listed as first author in five of them.

6.1.1 Research Papers

Achiam, M.A., & Evans, H.J. (in press). Out-of-school science education institutions for sustainability. *Amplifying Informal Science Learnings* (eds. Diamond & Rosenfeld).

Evans, H.J. (in press). The scope and status of sustainability education in out-of-school settings across Denmark. *Nordic Studies in Science Education (NorDiNa)*.

Evans, H. J., & Achiam, M. (2021). Sustainability in out-of-school science education: identifying the unique potentials. *Environmental Education Research*, 1–22.

Tougaard, S., Achiam, M., Nicolaisen, L. B., & Evans, H. J. (2021). Naturvidenskabelige museer skal ikke tilstræbe neutralitet. *Danske Museer, 34*, 45.

6.1.2 Research Manuscripts

Evans, H.J., & Achiam, M. (manuscript). Expressions of agency in out-of-school sustainability programmes: moving towards guidelines for sustainability education.

6.1.3 Popular Science

Evans, H.J. (2021). Operationalising sustainability in zoos and aquaria. *WAZA News Magazine*, 2, 17-19.

6.2 Conferences

Across the three years, I have attended eight conferences; presenting at four of them.

6.2.1 Presentations

Danish Association of Zoos and Aquaria (DAZA) Educators Conference, October 2021, Ree Park Safari, Denmark (presented in person). Keynote speaker, 2-hour workshop titled 'Sustainability in Out-of-School Science Education: Moving towards the Future'.

European Conference on Educational Research (ECER), September 2021, Geneva, Switzerland (online conference, presented online). 30-minute panel session (20-minute presentation, 10-minute Q & A) titled 'The Educational Significance of Sustainability in Out-of-School Settings'.

International Council of Museums (ICOM) International Symposium on Museums and Sustainability, November 2021, Zhejiang Museum of Natural History, Hangzhou, China (hybrid conference, presented online). Keynote speaker, 30-minute panel session (20-minute presentation, 10 minute Q & A) titled

'Sustainability in Out-of-School Science Education: Identifying the Unique Potentials'.

Klimahaus Symposium, September 2020, Bremerhavn, Germany (hybrid conference, presented online). 30-minute panel session (20-minute presentation, 10-minute Q & A) titled 'Museums and Sustainability: The Unique Potentials'.

6.2.2 Other Conferences Attended

European Network of Science Centres and Museums (Ecsite), June 2019, Experimentarium, Copenhagen, Denmark. 'Pushing Boundaries'. Attended in person.

European Science Education Research Association (ESERA), August/September 2021, organised by the University of Minho, Braga, Portugal. Online.

Klimahaus Symposium, June 2019, Bremerhavn, Germany. Attended in person.

World Association of Zoos and Aquaria (WAZA), October 2020. Online.

6.3 Courses

The courses attended add up to 30 ECTS, with a breakdown listed below.

6.3.1 PhD Courses

- Content Analysis in Mathematics and Science Education (5 ECTS) – October 2019
- ESERA Virtual Doctoral Network – Summer School (4 ECTS) - June-July 2020
- Introduction Course for New PhD Students (3 ECTS) – June 2019
- Introduction to University Pedagogy (3 ECTS) – October 2020
- Qualitative Methods (2 ECTS) – December 2020-February 2021
- Research Group Journal Club (2 ECTS) – April 2019-February 2022 (see 6.3.2. below)
- Supervision of BSc and MSc Students (1 ECTS) – October-November 2020
- Visual Methods (5 ECTS) – May 2019
- Writers Development (5 ECTS) – January-February 2020

6.3.2 Research Group Journal Club

I have attended eleven Journal Clubs, and led two of them. This is a group formed of researchers from across the University of Copenhagen, and additional institutions such as Roskilde University and Stockholm University. The format involved the choosing of one or two research papers for reading in detail prior to the meeting, with discussions taking place during the meeting that review and comment on the research. 2020 was greatly impacted by the coronavirus pandemic, with efforts instead focused on the preparation of teaching courses for online learning.

Below is a breakdown of the dates and research papers for the eleven Journal Clubs:

1. **26th April 2019** (Science museums)

Mortensen, M. F. (2011). Analysis of the educational potential of a science museum learning environment: Visitors' experience with and understanding of an immersion exhibit. *International Journal of Science Education*, *33*(4), 517–545. https://doi.org/10.1080/09500691003754589

2. **16th May 2019**

Sandoval, W. (2014). Conjecture Mapping: An Approach to Systematic Educational Design Research. *Journal of the Learning Sciences*, *23*(1), 18–36. https://doi.org/10.1080/10508406.2013.778204

3. **23rd March 2021** (Climate change)

Walsh, L. (2017). Understanding the rhetoric of climate science debates. *Wiley Interdisciplinary Reviews: Climate Change*, *8*(3), 1–7. https://doi.org/10.1002/wcc.452

Bradshaw, C. J. A., Ehrlich, P. R., Beattie, A., Ceballos, G., Crist, E., Diamond, J., Dirzo, R., Ehrlich, A. H., Harte, J., Harte, M. E., Pyke, G., Raven, P. H., Ripple, W. J., Saltré, F., Turnbull, C., Wackernagel, M., & Blumstein, D. T. (2021). Underestimating the Challenges of Avoiding a Ghastly Future. *Frontiers in Conservation Science*, *1*(December). https://doi.org/10.3389/fcosc.2020.615419

4. **21st April 2021** (Henry led - Science Fiction)

Gendron, C., Ivanaj, S., Girard, B., & Arpin, M. L. (2017). Science-fiction literature as inspiration for social theorizing within sustainability research. *Journal of Cleaner Production*, *164*, 1553–1562. https://doi.org/10.1016/j.jclepro.2017.07.044

5. **21st May 2021** (Arts-Based Methods)

Heinrichs, H. (2018). Sustainability Science with Ozzy Osbourne, Julia Roberts and Ai Weiwei. *Gaia*, *27*(1), 132–137.

6. **30th June 2021** (Climate Sorrow)

Todd, S. (2020). Creating Aesthetic Encounters of the World, or Teaching in the Presence of Climate Sorrow. *Journal of Philosophy of Education*, *54*(4), 1110–1125. https://doi.org/10.1111/1467-9752.12478

7. **16th September 2021** (Environmental Education)

Hursh, D., Henderson, J., & Greenwood, D. (2015). Environmental education in a neoliberal climate. *Environmental Education Research*, *21*(3), 299–318. https://doi.org/10.1080/13504622.2015.1018141

8. **1st November 2021** (Climate Change Education)

Ojala, M. (2013). Coping with climate change among adolescents: Implications for subjective well-being and environmental engagement. *Sustainability (Switzerland)*, *5*(5), 2191–2209. https://doi.org/10.3390/su5052191

Boström, M., Andersson, E., Berg, M., Gustafsson, K., Gustavsson, E., Hysing, E., Lidskog, R., Löfmarck, E., Ojala, M., Olsson, J., Singleton, B. E., Svenberg, S., Uggla, Y., & öhman, J. (2018). Conditions for transformative learning for sustainable development: A theoretical review and approach. *Sustainability (Switzerland)*, *10*(12). https://doi.org/10.3390/su10124479

9. **6th December 2021** (Comics)

Farinella, M. (2018). The potential of comics in science communication. *Journal of Science Communication*, *17*(1), 1–17. https://doi.org/10.22323/2.17010401

10. **20th January 2022** (Henry led – Virtual Reality)

Shehade, M., & Stylianou-Lambert, T. (2020). Virtual reality in museums: Exploring the experiences of museum professionals. *Applied Sciences (Switzerland)*, *10*(11). https://doi.org/10.3390/app10114031

11. **21st February 2022** (Storytelling)

Phillips, J. (2021). Storytelling in Earth sciences: The eight basic plots. *Earth-Science Reviews, 115: 153-162.*

Morris, B.S. et al., (2019). Stories vs. Facts: triggering emotion and action-taking on climate change. *Climatic Change,* 154: 19-36.

6.3.3 Other Courses

The Sustainable Development Goals – A global, transdisciplinary vision for the future. Coursera, December 2019-January 2020.

6.4 Teaching

6.4.1 Introduction Course for New PhD Students

Three occasions. Once in-person in February 2020 (4-days), twice-online in November 2020 and March 2021 (5-days each). Also co-adapted the course to make it suitable for online teaching.

6.4.2 Science Communication in Theory and Practice

Seven weeks, July-August 2020 – online, course contributor.

Seven weeks, July-August 2021 – online, co-course leader.

6.4.3 Citizen Science

A 3-hour workshop on citizen science to Danish Master students attending a Science Communication course, December 2020.

6.5 Supervision

I have supervised five student projects across Bachelor and Master level; all students listed were co-supervised with Marianne Achiam.

1. Nicole Alexandra Brooks, Bachelor Thesis in Biology, 5th June 2020 (30 ECTS). *How zoo signs can help save the world: a literature review and analysis on sustainable zoo signage communication in Copenhagen Zoo.*

2. Marie Berg Rose-Møller, Bachelor Project in Practice in Biology, 22nd January 2021 (15 ECTS). *Copenhagen Zoo: Research and Conservation.*

3. Julia Sampedro Cerviño, Master Project Out of Scope in Climate Change, 22nd June 2021 (2.5 ECTS). *Key elements of sustainability leadership education. Climate-KIC Summer School as a study case: The coaches' perspective.*

4. Cecilie France Jarsmer Mathiesen, Bachelor Project in Practice in Geography, 19th January 2022, (15 ECTS). *Fonden Golden Days.*

5. Julia Sampedro Cerviño, Master Thesis in Climate Change, 28th January 2022, (30 ECTS). *The Head, Hands and Heart Dimensions of a Sustainability Transformational Learning Experience: The Climate-KIC Journey as a Study Case.*

6.6 Research Visits Abroad

Two research stays have taken place, including three weeks in Hong Kong and two months in London.

6.6.1 Hong Kong

In September-October 2019, I carried out a three-week research trip to Hong Kong, involving collaborations with the following three OSSEIs: Museum of Climate Change, Hong Kong Science Museum and Ocean Park. I interviewed educators and observed school programmes associated with sustainability. Results indicated strong linkages between school curriculum content and the sustainability programmes offered by the museum - to attract school visits. In addition, the Museum of Climate Change has undertaken a recent change in dissemination strategy, from facts-based to more action-orientated. I incorporated the observed practice into illustrations in Paper One, within conference presentations and teaching content.

6.6.2 London

In April-May 2021, I carried out a two-month research stay at Kings College London, working with Heather King and Melissa Glackin. I presented the thesis to the Centre for Research in Education in Science, Technology, Engineering & Mathematics (CRESTEM) group, collaborated with other researchers and continued writing on Paper Two.

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8.0 Appendix

INVITATION TIL WORKSHOP

Inspiration og guidelines til design af undervisningsforløb om bæredygtighed

Fredag den 25. marts 2022 kl. 9.00 – 15.00 afholder vi workshop for jer praktikere fra zoologiske haver, akvarier, science centre og naturvidenskabelige museer, der udvikler, designer og underviser i skoleforløb med fokus på bæredygtighed.

Henry James Evans og Marianne Achiam fra forskergruppen **Science Communication** ved Institut for Naturfagenes Didaktik, KU vil præsentere projektet *Sustainability in Out-of-School Science Education* og diskutere bæredygtighedsundervisning i eksterne læringsmiljøer i Danmark.

Henry James Evans vil præsentere et sæt guidelines, som er udviklet i projektet, og som kan bidrage til udvikling og design af forløb til skoleklasser. Disse guidelines vil blive eksemplificeret gennem tre praktiske undervisningsforløb fra Københavns ZOO, Økolariet og Dansk Teknisk Museum.

Efter de faglige oplæg, hands-on aktiviteter og praktiske erfaringer fra undervisningsforløbene, vil vi i workshops tale om brugen af guidelines i forhold til jeres egne erfaringer med og udvikling af undervisningsforløb.

Det vil undervejs i programmet være muligt at se og afprøve aktiviteter fra de tre undervisningsforløb.

Vi glæder os til at se jer
Henry James Evans og Marianne Achiam

*Jeg hedder **Henry James Evans** og er ved at afslutte mit ph.d.- forløb ved Københavns Universitet (afl. 31. marts 2022). Jeg forsker i bæredygtighedsundervisning i eksterne læringsmiljøer i Danmark. Her bruger jeg både teori og praksis til at undersøge begrebet bæredygtighed. Forskningen vil udmønte sig i udviklingen af guidelines, der kan anvendes af praktikere i eksterne læringsmiljøer.*

*Jeg hedder **Marianne Achiam** og er lektor på Københavns Universitet, hvor jeg leder forskergruppen Science Communication. Min undervisning og forskning fokuserer på kommunikation og formidling af naturvidenskab. Jeg er særligt interesseret i, hvordan institutioner som science centre og museer kan være med til at drive den grønne omstilling og skabe en mere bæredygtig fremtid.*

PRAKTISK

DATO:
Fredag den 25. marts 2022 kl. 9.00 – 15.00.
Workshopdagen er gratis og inkl. forplejning.
Rejseudgifter for op til DKK 500 refunderes mod bilag.

STED:
Adresse: Institut for Naturfagenes Didaktik,
Københavns Universitet
Rådmandsgade 64, 2200 København

DEADLINE:
Tilmeld dig senest 1. februar 2022
til Pia Maria Lie pml@piamarialie.dk

Workshoppen er støttet af
nordisk fonden

INVITATION TIL WORKSHOP

Inspiration og guidelines til design af undervisningsforløb om bæredygtighed

PROGRAM

09.00 – 9.45
Morgenmad og aktiviteter

09.45 – 9.50
Velkommen
V. Marianne Achiam og Henry James Evans

09.50 – 10.00
Oplæg: *Eksterne naturfaglige læringsmiljøer og wicked problems*
V. Marianne Achiam

10.00 – 10:30
Oplæg: *Sustainability in out-of-school science education*
V. Henry James Evans

10.30 – 10.45
Pause og aktiviteter

10.45 – 12.00
Oplæg og snapshots: *Guidelines*
V. Henry James Evans

12.00 – 12.45
Frokost og aktiviteter

12.45 – 14.15
Workshops om guidelines og egne erfaringer

14.15 – 14.30
Kaffe og aktiviteter

14.30 – 14.50
Opsamling og diskussion

14.50 – 15.00
Tak for i dag og evaluering

Snapshot: *Hjælp chimpansen*
V. Ditte Sofie Andersen, Københavns ZOO

Snapshot: *Verden varmer op*
V. Sabrina Louise Rand, Økolariet

Snapshot: *Sort Energi og grønne håb*
V. Birgitta Præstholm, Dansk Teknisk Museum

Workshoppen er støttet af
nordisk fonden

	Guidelines for planning teaching courses	Examples from teaching courses
SDGs	**Use the World Goals actively** The world goals are recognizable and they show the connections between the different problems.	Use the world goals actively in the teaching, by showing concrete connections between the goals and the children's everyday life. Also use them to show that many sustainability issues are related.
Connectedness	**Create a sense of togetherness** The children's sense of togetherness or connection with their surroundings is crucial for them to be able to act sustainably. Children can express cohesion by expressing wonder, excitement and joy at their surroundings, and by expressing their relationship to the surroundings, often in an intuitive or emotional way.	Try to create a sense of togetherness with the surroundings (whether the surroundings are designed or natural) by helping the children to notice and observe their physical surroundings.
Engagement	**Help the kids get involved** Children can go from a sense of togetherness to a deeper commitment by exploring their surroundings. They move from an intuitive to a more concrete connection through direct or indirect contact and interaction with the environment.	Make sure there is time and opportunity for the children to discover their surroundings, whether it is an exhibition, a facility, or a nature area. Allow the children to interact in as many ways as possible, with all their senses. Allow the children to seek additional information about what interests them.
Critical questions	**Encourage/support critical questions** Children's critical awareness and sense of justice are aroused when they move from being committed to being critical of the sustainability issues - and the lack of solutions. It can be a way for kids to start finding their own voice.	Help the children to (dare) ask their own critical questions, for example about the adults' slow reaction to the sustainability problems. Help them discover the complexity of the problems and the framework conditions that make it difficult to act on the problems (political, economic conditions, etc.)

	Guidelines for planning teaching courses	Examples from teaching courses
Believe in your own ability	**Contribute to the children's hope and confidence in their options for action** Hope is a necessary part of children's belief that they can act sustainably. Children need to be able to see and understand sustainability issues in an optimistic light in order to build confidence in their own ability - and ability - to make a difference.	Make sure that the teaching process frames the sustainability problems in a positive or constructive way that gives the children hope by pointing to concrete and realistic solutions to the sustainability problems.
Take a position	**Help the children stand firm in their beliefs** It is difficult for children to participate in sustainability initiatives because they may be opposed by the adults or their own peers. But if they can overcome these difficulties, they have the opportunity to take a clear stand, and act purposefully.	Make sure that the teaching process - and the institution - helps the children to overcome the lack of support from their surroundings, for example by creating or contributing to communities, and to support them in taking a clear position.
Targeted action	**Give the children the opportunity to act on their convictions** When children can deal with the problems in their own physical and social context (at home, in the classroom, on the shopping trip) in a conscious, informed and targeted way, they get involved in - or even take the initiative to - act sustainably.	Make sure that the teaching process helps the children to define and qualify their own approach to acting on the sustainability issues. Different approaches can work for different children, and the teaching process can help the children find the approach that works best for them.

Questions for Discussion

1. What thoughts do you get when you read these guidelines?

2. Are there any of these guidelines that you already use when planning teaching courses?

3. Are some of these guidelines difficult to use - and why?

4. **Choose three guidelines that best suit the teaching and dissemination practice you have, and why?** Feel free to give examples from your teaching offers to the intermediate level.

5. What challenges do you have in working with sustainability in teaching?

6. Are these challenges different from those you experience when teaching other subjects? If so - why?

7. Will these guidelines be able to help you the next time you plan a teaching course that focuses on sustainability? In which way?

9.0 Contributing Papers

Paper One.

Sustainability in Out-of-School Science Education: Identifying the Unique Potentials

Evans & Achiam, (2021), *Environmental Education Research*

Paper Two.

The Scope and Status of Sustainability Education in Out-of-School Settings across Denmark

Evans, (in press), *Nordic Studies in Science Education*

Paper Three.

Expressions of Agency in Out-of-School Sustainability Programmes: Moving Towards Guidelines for Sustainability Education

Evans & Achiam, (manuscript)

Paper Four.

Museum Beyond Neutrality

Evans, Nicolaisen, Tougaard & Achiam, (2020), *The Journal of Nordic Museology*

9.1 Paper One

Sustainability in Out-of-School Science Education: Identifying the Unique Potentials

Evans & Achiam, (2021)

Abstract

Out-of-school science education institutions, such as museums, science centres, zoos and aquaria, have strong potentials to promote sustainability, yet seem to lack an operational definition of sustainability that aligns with their specific characteristics and institutional remit. Here, we use the anthropological theory of didactics to systematically develop such an operational definition, designated as the reference model. We draw on literature from research and practice to account for the features of sustainability science and policy, as well as the different specific strengths of out-of-school science education institutions, to identify unique potentials for sustainability education. These potentials are synthesised and illustrated in a set of institutionally specific guidelines that optimise the organisation of sustainability for each kind of out-of-school science education institution. We conclude by considering the implications of our findings for sustainability education.

Introduction

Humanity is facing global challenges that are unprecedented in scale. Rising global temperatures, plastic pollution, biodiversity loss, deforestation and many other environmental issues require urgent and comprehensive action worldwide. In addition, large-scale social and economic issues such as poverty and inequality continue to affect millions of people across the world (Brandt et al., 2013; Jerneck et al., 2011). Sustainability is a notion ubiquitous in society today (Stevenson, Ferreira, & Emery, 2016). Although it has been interpreted in various ways (Purvis, Mao, & Robinson, 2018), there is wide-spread consensus that the three dimensions of environment, society and economics play major roles (e.g. Goodland, 1995; Lele, 1991; Martens, 2006; McFarlane & Ogazon, 2011). For instance, Kates, (2011:19449) refers to sustainability as the ability to meet 'the needs of the present and future generations while substantially reducing poverty and conserving the planet's life support systems'.

Although achieving sustainability on a global scale is a daunting task, education has been identified as a crucial means to this end (e.g. Holfelder, 2019). This form of education is called sustainability education, also referred to in the literature as education for sustainable development and education for sustainability (Aikens, McKenzie, & Vaughter, 2016). These terms have been supported by the United Nations (UN) (Stevenson, Ferreira, & Emery, 2016) and incorporated into their educational programmes, with 2005–2014 the Decade of Education for Sustainable Development (Holfelder, 2019). Sustainability education goes beyond changing knowledge, awareness and behaviour, to providing society with the skills for effective leadership and management that aids humanity in moving towards systemic change for global sustainability (Steinfeld & Mino, 2009).

Recent literature has pointed to out-of-school science education as an especially important arena for preparing citizens for a sustainable future (e.g. Clayton, 2017; Dillon, 2017; Janes & Grattan, 2019; Janes & Sandell, 2019; Logan & Sutter, 2012; Sellmann & Bogner, 2013; Sutton et al., 2017). Out-of-school science education institutions (OSSEIs), such as museums, science centres, zoos and aquaria are globally distributed, receive large numbers of visitors annually, hold a high level of trust within society and across different political backgrounds, whilst also appealing to a diverse age-range (Cameron, Hodge, & Salazar, 2013; Clayton, 2017; Sutton et al., 2017). They thus have great potential worldwide, in reaching out to communities to contribute in changing the present day mind-set that is threatening the future of humanity on planet Earth (McFarlane & Ogazon, 2011).

With this study, we seek to substantiate and qualify the claim that OSSEIs have a unique role to play in promoting global sustainability, that is, they can offer something due to their specific institutional conditions

and practices that the formal school system cannot. We do this by developing the notion of sustainability based on not only its existing manifestations in out-of-school science education, but also on its *possible* manifestations. In the following section, we describe our methodological proposal and circumscribe the system under study. This system includes scholarly knowledge on sustainability (in the form of the still-emerging research domain of sustainability science), critical societal actors involved in deciding sustainability (education) policy, and the range of OSSEIs where sustainability education can potentially take place. Taking into account important features of sustainability that are simultaneously of relevance to OSSEIs and sanctioned by critical societal actors, we distil from this system the unique potentials (and conversely, the missed opportunities) for the institutions' sustainability education.

Conceptual Framework

Although there seems to be widespread agreement that OSSEIs are well situated to provide sustainability education, sustainability is not easily translated into practice in museums and other cultural institutions (Brown, 2019; Cameron, Hodge, & Salazar, 2013; Hedges, 2020; Keogh & Möllers, 2015). This has important implications for OSSEIs, whose efforts to provide sustainability education may be constrained by the lack of an operational definition of sustainability that aligns with their characteristics and remit. Without such a definition or framework, sustainability education risks being governed by the unpredictable funding patterns, serendipity, specialised campaigns and local idiosyncrasies that are reality for OSSEIs, rather than by a strong alignment between institutional strengths and sustainability objectives.

Although it is provocative, and potentially fraught, to offer examples of missed opportunities in sustainability education, we cautiously lay out a number of instances that we believe support our argument. The first example involves an exhibition about human origins in an American natural history museum. This exhibition was notably funded by the owner of a large energy and chemical conglomerate, who once claimed that the current climate disruption might be beneficial to humans (Little, 2015). In his critique of the exhibition, Little discusses how it positions sudden, drastic climate change as part of a natural continuum, thereby indirectly whitewashing the present climate crisis. In another example from 2019, a Norwegian museum about fossil fuels opened an exhibition about sustainability. During a visit, the second author experienced this exhibition as a clear departure from the approach taken in other parts of the museum. In these, personal narratives, interactives, and awe-inspiring machinery and equipment had made for a compelling experience of fossil fuel extraction in Norway. In comparison, the sustainability exhibition was governed by text and diagrams, illustrating perhaps the difficulty of aligning the complex topic of sustainability with the object-based modality that is the museum's established area of expertise. Finally, a UK-based science and technology

museum ran an interactive exhibition on climate change in 2009. This exhibition was critiqued by Jones, (2009) for being patronising, who pointed out that the majority of visitors who interacted with the exhibition ended up voting against the scientific consensus on climate change. Taken together, we suggest these three examples (and others) illustrate how sustainability has not been operationalised for out-of-school science education, and why science education professionals may well be anxious and doubtful about designing sustainability education (cf. Becker, 2017; Kaufman, 2012).

In response, we suggest that it might be valuable with a perspective on sustainability that comes from outside the institutions in question. Such a perspective could consider not only what OSSEIs are presently doing, but also what they potentially could be doing. The method to systematically construct such a point of reference has been developed in the research programme of the anthropological theory of didactics (ATD), which concerns itself with the diffusion of scientific knowledge through society and social institutions (e.g. schools or museums) and the conditions and constraints that govern that diffusion (Chevallard & Bosch, 2014). ATD thus views society and its institutions as nested layers in an *ecosystem* that conditions and constrains scientific knowledge in different ways. Although it originated as a framework for research in school-based education systems, ATD has been used by researchers since the mid-1990s to understand how science diffuses through the parallel system of OSSEIs (Marandino & Mortensen, 2010). Here, we draw on the out-of-school branch of ATD research, to analyse the conditions and constraints imposed by the ecosystem of sustainability that (potentially) shapes sustainability education. It is not our goal to provide an exhaustive analysis of this ecosystem; rather, we use 'confirming sampling' to identify conditions and constraints relevant to OSSEIs, building upon previous results (cf. Fraenkel, Wallen, & Hyen, 2012). In the following, we provide further details of the conceptual framework.

The Anthropological Theory of Didactics

According to ATD, what is taught in education institutions originates elsewhere, in universities or other 'scholarly' institutions, where it is adapted to a particular set of conditions. In order to become teachable and learnable, scientific knowledge must therefore be deconstructed and reconstructed into a suitable form (Chevallard & Bosch, 2014). Generally, this deconstruction and reconstruction, or *didactic transposition*, takes place in two steps: first, elements of scholarly knowledge are selected to be taught or disseminated, and second, the selected elements of knowledge are transformed into a teachable form. The first step is governed by the so-called *noosphere*, which broadly speaking includes anyone voicing opinions about what knowledge should be taken up in education (Rasmussen, 2017). This includes stakeholders and decision makers whose official role it is to respond to the demands made by society on educational institutions, for

instance, when a ministry formulates criteria for science centres to receive government funding, or when a specialised organisation creates a definition of 'museum'. The second step in the de/reconstruction of knowledge is governed by those who carry out teaching and dissemination, and involves the transformation of selected content into activities, installations, and other manifestations of pedagogical intentions in concrete education situations (Chevallard & Bosch, 2014). The general ecosystem thus described is summed up by Figure 1.

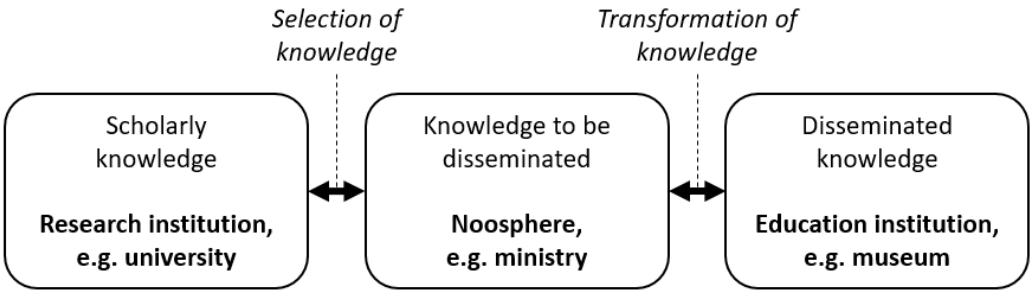

Figure 1. Didactic transposition: The general process by which scholarly knowledge, constructed in research institutions, is deconstructed and reconstructed into a suitable teachable form that suits the institutional conditions of an OSSEI, such as a museum. This process involves first the selection of knowledge by actors in the noosphere, then the transformation of knowledge by educators and disseminators. Adapted from Chevallard & Bosch, (2014).

The model of didactic transposition explains why knowledge is relative to the institution it exists within, and describes the process by which an object of knowledge becomes an object of dissemination through a process of transformation (Moormann & Bélanger, 2019; Sandholdt & Achiam, 2018; Simonneaux & Jacobi, 1997). Perhaps most importantly, the model of didactic transposition indicates some of the complexity involved in producing objects of teaching. Among other things, this complexity means that the versions of knowledge found in educational institutions are not always the optimal ones. For instance, Nicolaisen & Achiam, (2019) found that an exhibition on space exploration had inadvertently 'inherited' the masculine gendering found in the scholarly domain of astronomy and space technology, even though the exhibition was intended for audiences across the gender spectrum. In another example, Bueno & Marandino, (2017) showed how the specifics of a chosen exhibit format constrained how biodiversity-related knowledge about the Amazon could be embodied, to the point of undermining the notion of biodiversity itself. Finally, Mortensen, (2010; 2011) showed how the everyday notions of exhibit designers encroached on biological knowledge in the development of an exhibit about animal adaptations, ultimately causing learners to misinterpret the message

of that exhibit. These studies and others remind us that we should not assume the way knowledge is organised in a given situation is the best one. As science education researchers, we should not uncritically accept the way knowledge is organised in a given situation, but rather, consider and account for alternative and relevant organisations of that knowledge.

ATD provides a tool, the reference model, to carry out this accounting in a systematic way. The reference model can be used in both critical analysis and productive design perspectives. In a critical analysis perspective, the reference model can be used to validate appropriate organisations of knowledge or point out inconsistencies or infelicities in them (cf. Achiam, Simony, & Lindow, 2016; Bueno & Marandino, 2017). In a productive design perspective, the reference model can be used to create organisations of knowledge optimised for specific teaching purposes (cf. Achiam, Lindow, & Simony, 2019). In either case, the reference model is a means to account for the relevant organisations of a particular object of knowledge in its educational ecosystem (Figure 2).

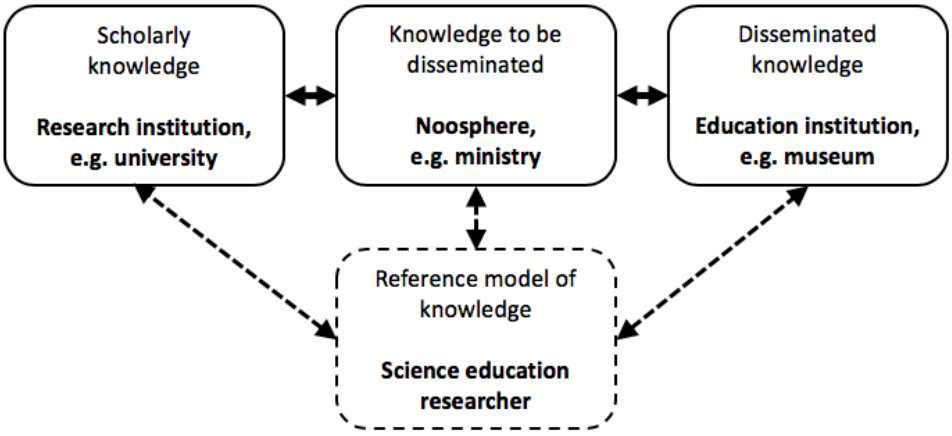

Figure 2. The reference model is the explicit epistemological point of reference taken by the science education researcher, as suggested by ATD. It takes into account the relevant organisations of knowledge that exist in the contexts involved in didactic transposition, and can be used in a critical analysis perspective or a productive design perspective. Adapted from Chevallard & Bosch, (2014).

Here, we use the reference model in the latter sense, i.e. in a productive design perspective. We seek to construct an organisation of sustainability optimised for the purposes of OSSEIs. The educational ecosystem under study here thus includes the research domain of sustainability, societal actors within the noosphere,

such as the UN, and OSSEIs that carry out sustainability education (Figure 3). All domains involved in the didactic transposition process within the educational system are treated equally (Chevallard & Bosch, 2014).

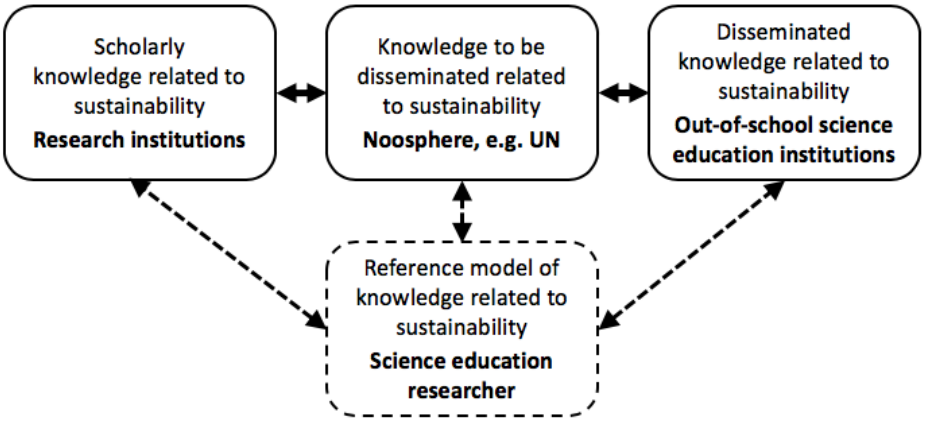

Figure 3. The education system adapted for sustainability, designated here as the 'ecosystem of sustainability education'.

The Ecosystem of Sustainability Education

We now define and analyse the ecosystem of sustainability education to build a reference model of knowledge related to sustainability (Figure 3), optimised for the purposes of OSSEIs. We elaborate on elements within the scholarly knowledge and noosphere domains that are simultaneously important features of sustainability and of relevance to the institutions in question. Finally, we synthesise these elements in terms of OSSEIs and how they can optimally contribute to preparing citizens in navigating the necessary steps towards a more sustainable society.

Sustainability Science

Sustainability science is an umbrella term (Kastenhofer, Bechtold, & Wilfing, 2011; Shahadu, 2016) that aims to 'make the normative concept of sustainability operational' (Spangenberg, 2011:276). This relatively young field studies the interactions between natural and social systems (Clark, 2007; Clark & Dickson, 2003; Kates, 2001; Spangenberg, 2011), as well as how those interactions affect humanity's ability to meet the needs of present and future generations (Kates, 2011). To sufficiently understand the behaviour of these systems, gaining knowledge on individual elements within them is not enough (Clark & Dickson, 2003). The integration of systems is critical in understanding the interconnected nature of sustainability, involving methods that combine elements of intertwined human and natural systems, across the dimensions of space, time and organisational level (Liu et al., 2015).

Spangenberg, (2011) describes two forms of sustainability science: the monodisciplinary science *for* sustainability and the transdisciplinary science *of* sustainability. Briefly, science *for* sustainability takes a 'knowledge-first approach', and includes the descriptive-analytical basic research that is carried out within or in parallel between traditional scientific disciplines. Science *of* sustainability includes transformational, process-oriented approaches that are driven by real-world problems and thus inherently interdisciplinary (Clark, 2007; Miller et al., 2014; Wittmayer & Schäpke, 2014). The emergence of science *of* sustainability has been described as a response to the new challenges that emerged from the problems of sustainable development themselves (Martens, 2006; Spangenberg & Connor, 2010) because, it is suggested, the problems of sustainability cannot be solved by the same mentality that helped create them (Einstein's dictum, cf. Spangenberg, 2011; Fang et al., 2018). In the present paper, we focus on the science *of* sustainability (hereafter: 'sustainability science'), which necessarily transcends, and critically reflects on, the boundaries of the traditional science disciplines.

Sustainability science is transdisciplinary

As mentioned, due to the broad nature of global sustainability problems that include environmental, economic and social dimensions, sustainability science is a transdisciplinary process working simultaneously between, across and beyond disciplines. This 'integrative science' works to break down boundaries found between disciplines (Barrett, 2001; Martens, 2006), with many different disciplines of science working collaboratively (interdisciplinary) to study mutual problems (Brandt et al., 2013; Kim & Oki, 2011). Multiple disciplines partake in both research and dissemination, and methods are transferred across disciplines, allowing for the integration of data (Spangenberg, 2011).

Sustainability science involves extended peer communities

Sustainability science is located at the intersection between science and policy; between scientists, decision makers, and the public (Spangenberg, 2011). It is important for sustainability science to involve actors from outside academia to generate integrated solution options and create ownership across stakeholder groups (Craps, 2019; Lang et al., 2012). Inclusive participatory processes are employed that involve the scientific community, stakeholders in society (i.e. policymakers, business representatives and social institutions) and citizens themselves (Kates, 2001; Martens, 2006; Spangenberg, 2011). This means that in sustainability science, instead of being given priority in finding solutions, science is just one kind of contribution to a discursive process of joint knowledge construction (Brandt et al., 2013). In this way, the different groups of stakeholders become an extended peer community of sorts for the scientists - and vice versa (Spangenberg, 2011).

The involvement of different groups of stakeholders is challenging. Generally speaking, scientists, policymakers and the public are 'epistemologically distant' from one another, meaning that when they make sense of sustainability problems, they use differing analytical paradigms (Garvin, 2001), and may evaluate for instance the credibility or salience of findings in very different ways (Lang et al., 2012). As a result, the uncertainty that characterises decision-making processes in sustainability science cannot always be resolved, but rather managed through different engagement models (Brandt et al., 2013; Martens, 2006).

Sustainability science addresses real-world problems

By definition, sustainability science addresses problems that arise in the interactions between global, social and human systems (Komiyama & Takeuchi, 2006). This means that sustainability science deals with societally relevant, purpose-bound problems that often differ qualitatively from the primacy of science or value-free stance characteristic of the traditional scientific approach (Kauffman, 2009; Lang et al., 2012). These 'wicked' problems are complex, require immediate action and impact far into the future on both global and local scales (Brundiers, Wiek, & Redman, 2010; van der Leeuw et al., 2012).

Sustainability science takes a global and local perspective

A growing number of scholars emphasise the place-based nature of sustainability science (Devine-Wright, 2013; Potschin & Haines-Young, 2013), reminding us that the environmental movements of the 19th and 20th centuries that preceded sustainability science were fundamentally about place and geography (Shrivastava & Kennelly, 2017). A sense of place can be important on both the global and local level (Feitelson, 1991). The phrase 'think global, act local' has become a popular part of rhetoric on the sustainability agenda over recent decades, leading to the belief that sustainability issues on a global scale can be translated into a comprehensible form on a more personal scale (Jasanoff, 2010). Although sustainability science plays out on many spatial scales from global to local (Kates 2001; Martens, 2006), it is argued that to be more than an abstract idea, sustainability and its associated challenges (e.g. climate change) must be operationalised at a local or regional scale (Martens, 2006), compared to one focused on distant regions and their habitats (Brace & Geoghegan, 2010). Further, because a key element of sustainability science is the successful establishment of extended peer communities, it is necessary to engage with the place-based knowledge of local publics and decision-makers (Brandt et al., 2013, Potschin & Haines-Young, 2013).

Sustainability science has a temporal aspect

Sustainability focuses on the future that humanity will face, meaning that it has an embedded temporal element (Cavender-Bares et al., 2015). In addition, our understanding of many of the problems we face today comes from an awareness of the past (Goeminne & Paredis, 2010; Markley, 2012). For instance, the

reconstruction of Earth's past climate, which is the basis of our present understanding of climate change, relies on historical records such as ice cores (e.g. Dansgaard et al., 1993), tree rings (e.g. Fritts, Lofgren, & Gordon, 1980), and sediment layers (e.g. Tian, Nelson, & Hue, 2011) that reveal signs of long-term temperature variability. Our observation of the present biodiversity crisis would have been impossible without baseline records of past biodiversity (e.g. Fonseca et al., 2001; Suarez & Tsutsui, 2004). Despite this, general conceptions of sustainability science lack a temporal perspective (Munasinghe & Swart, 2005). Accordingly, sustainability scholars have suggested adding a temporal dimension to definitions of sustainable development (Martens, 2006; Seghezzo, 2009). This dimension foregrounds the differences in speed of human and non-human activities, for instance, agricultural techniques that degrade the productivity of soil versus the long cycles of regeneration periods (Held, 2001).

In summary, the features of sustainability science that are of particular relevance to the present study are transdisciplinarity, the engagement of extended peer communities, a focus on real-world problems, a global and local perspective, and the temporal aspects of sustainability. We turn now to survey how sustainability is discussed and formulated in the noosphere, by decision-makers and other actors who have a stake in what aspects of sustainability should be taken up in education. As we shall see in the following section, notions of sustainability are shaped by noosphere conditions and constraints that are quite different to those that govern the research domain of sustainability science.

Sustainability in the Noosphere

In 1987, sustainability appeared on the world-stage via the UN World Commission on Environment and Development (WCED) report titled *Our Common Future,* also known as the Brundtland Report (WCED, 1987). Globally, it received substantial political backing on the critical need for sustainability action (Goodland, 1995), and prompted an ever-growing discussion in the noosphere about sustainability in relation to society and education. As we lay out in the following, actors in the noosphere, from overarching organisations of human civilisation to national institutions, have opinions about sustainability and its societal and educational significance.

One of the most pervasive conceptions of sustainability in the noosphere is that of the UN Sustainable Development Goals (SDGs) (Purvis, Mao, & Robinson, 2018), forming a large part of the 2030 Agenda for Sustainable Development (UN, 2015). The seventeen goals focus on different aspects of the global 'wicked' problems we face (Weymouth & Hartz-Karp, 2018), while operationalising sustainability for policy and education worldwide. Their transdisciplinary nature reflects the idea that global action is required across environmental, economic and societal dimensions, by a coalition of actors more diverse than just

governments. The goals are linked through their interactions with each other via synergies (positive strides in one SDG that benefit another) and trade-offs (positive strides in one SDG that hamper another). The enhancement of synergies and finding solutions to trade-offs play an essential role in whether they are achieved (Kroll, Warchold, & Pradhan, 2019).

Criticisms of the SDGs focus on the severe lack of accountability for governments, industries and citizens (Spangenberg, 2017). In addition, the large number of targets and indicators provide a major obstacle in communicating them effectively to the public, engaging with policy, as well as the amount of monitoring and quantifying required to measure any progress. Further critique focuses on their contradictory nature, such as the difficult balancing act of achieving both growth focused and environmental goals (Liverman, 2018; Swain, 2018).

The SDGs afford bottom-up processes

The SDGs were created through a participatory and inclusive bottom-up process that involved input from more than 70 governments and many representatives of civil society (Biermann, Kanie, & Kim, 2017; Spangenberg, 2017). This process emphasised the role of businesses, cities, citizens, consumers and civil society as agents of change, and the resulting set of goals has been lauded for its potential to become the guiding vision for action across governmental, corporate and civil societies (Hajer et al., 2015). As they fundamentally break with prior attempts to create legally binding or top-down regulated global governance, the SDGs afford a large extent of national or even institutional discretion in interpreting and implementing the goals (Biermann, Kanie, & Kim, 2017). This allows for, but also requires, a strong degree of stakeholder-orientation, and provides space for the diversity of perspectives on sustainable development needed to engage a range of logics, actors and institutions (Hajer et al., 2015; Messerli et al., 2019; Mukhi & Quental, 2019).

The SDGs are amenable to adaptation

The SDGs are aimed at global application. However, because they are non-binding and have limited oversight, adaptation by more specialised organisations is necessary (Bierman, Kanie, & Kim, 2017). Indeed, a number of organisations with direct relevance to OSSEIs have incorporated aspects of the SDGs into their missions. For instance, in 2018 the International Council of Museums (ICOM) formed a working group to mainstream the SDGs across its activities and help its member museums support the SDGs (Brown, 2019). An objective in their 2020-2022 mandate is 'to inspire ICOM, its committees and members through science based data and strategies to embrace the SDGs and promote good practices in becoming energy efficient, sustainable institutions' (ICOM, 2020). An even stronger focus on science is found in the Tokyo Protocol, formulated by

the Science Centre World Summit (SCWS) in 2017, which observes that 'public engagement and action in science and technology are key to achieving the SDGs' and states that science centres and science museums worldwide are deeply committed to helping all people participate in the solutions to meet them (SCWS, 2017). Finally, during their annual conference in mid-October 2020, the World Association of Zoos and Aquaria (WAZA) released its 2020-2030 sustainability strategy, titled 'Protecting our Planet'. The report places a strong emphasis on guiding WAZA institutions to most effectively use their unique conditions in contributing to the achievement of the SDGs, through recommendations tailored for each of the 17 goals (WAZA, 2020). This particular organisation observes that their members make an effort to live in harmony with nature, and 'are helping their visitors and surrounding communities to take better care of the planet' (WAZA, n.d.).

The SDGs could be viewed as resulting from a series of global compromises made between development and sustainability, with their transdisciplinary nature an essential part of dealing with 'wicked' sustainability problems (Craps, 2019). Over the next decade, they will continue to play an influential role in shaping sustainability policy in the noosphere, with numerous organisations of direct relevance to OSSEIs absorbing them into their practices.

Out-of-School Science Education Institutions

As we have shown, sustainability is a widespread topic of discussion among scholars and academics, and pervades interactions between stakeholders, decision-makers and communities in the noosphere as well. In contrast, sustainability is 'seldom well-defined for museology' (Brown, 2019:3), meaning that when OSSEIs are indicated as key actors in sustainability education, broad and non-specific terms are used. Although we agree that OSSEIs share a number of characteristics, e.g. being free of curriculum constraints that characterise schools or focusing on providing a social, entertaining and educational experience for their visitors (Clayton, 2017), we contend that they also have important distinguishing features (cf. Cameron, Hodge, & Salazar, 2013). For instance, while museums define themselves in terms of the three pillars of collections, research and dissemination, science centres focus more on science/nature phenomena and interactive hands-on demonstrations (Schwan, Grajal, & Lewalter, 2014), and have neither collections nor their own scientific research function. Zoos and aquaria, in contrast, place a strong focus on conservation through 'living collections' (McCalman, 2017). In the following, we discuss the opportunities for sustainability education afforded by the particular institutional strengths that characterise different types of OSSEIs.

OSSEIs transcend disciplinary boundaries

Generally speaking, OSSEIs are not limited by the disciplinary boundaries that characterise school subjects, but instead have more systems-based perspectives. For instance, natural history museums often focus on cross-cutting content such as evolutionary relationships, systematics, biodiversity and ecosystem perspectives (King & Achiam, 2017), while science centres work across the disciplines in science & technology (Short & Weis, 2013) and zoos and aquaria often use the concept of biome to organise their content. This means that these institutions in different ways can enhance the integration of multiple scientific disciplines, a crucial feature of sustainability science (Martens, 2006).

OSSEIs are (becoming) inclusive and accessible

Recent years have seen a marked increase in discussions about the accessibility of out-of-school science education practices (Dawson, 2014). As a result, many OSSEIs have increased their efforts to provide visitors across gender, ethnic, ability and socioeconomic spectrums with appealing and equitable experiences (Achiam & Sølberg, 2017; Black, 2012). Further, as we have seen, the inclusion of a wide variety of perspectives seems crucial for understanding and addressing global sustainability challenges. Accordingly, there seems to be an important potential at the intersection of sustainability science, the SDGs and OSSEIs for framing conversations and activities that include scientific, lay, practical and indigenous knowledge (Messerli et al., 2019).

OSSEIs are hubs for dialogue and debate between science and society

OSSEIs are sites that encourage dialogue and debate, hold a high level of trust within society, and capture a broad audience (Ballard et al., 2017; Cameron, Hodge, & Salazar, 2013; Clayton, 2017; Logan & Sutter, 2012; Novacek, 2008). Practitioners view their institutions as being more than just a site for disseminating facts, but for 'collective deliberation of current issues' (Sutton et al., 2017:153). Holding this level of trust can allow OSSEIs to act as intellectually safe hubs for the general public to meet scientists and policymakers, creating interactions and dialogue between academic and non-academic practitioners (Rodegher & Freeman, 2019) that are legitimate experiments between different approaches (Pereira et al., 2015).

Citizen science involves the incorporation of both the natural and social sciences (Ballard et al*.,* 2017) and often exemplifies 'two-way knowledge sharing' (Sforzi et al., 2018). It provides an opportunity for the public and stakeholders in society to engage with scientists and take part in scientific research (Novacek, 2008). An increasing awareness felt within OSSEIs of the importance of being seen to engage in present-day sustainability issues, as well as the desire to enhance their public value, have led for example natural history museums to conduct a greater number of citizen science projects (Sforzi et al., 2018). These institutions often have elements of research and dissemination in the same building, providing suitable opportunities for

citizen science. These projects provide an opportunity for the public and stakeholders in society to engage with scientists and take part in scientific research (Novacek, 2008).

OSSEIs offer different modes of communication

Scientific research is usually codified, published and presented in a manner that is difficult for non-scientists to understand or even access. OSSEIs, on the other hand, have significant expertise in deconstructing scientific knowledge and reconstructing it according to their specific institutional modalities. This expertise provides important opportunities for the communication of sustainability science through tangible, multisensory and social experiences. The emphasis on the hands-on approach in many science centres encourages their visitors to explore and experiment (Short & Weis, 2013). Zoos and aquaria, on the other hand, stimulate emotion and empathy among their visitors by focusing on the conservation of biodiversity, and providing immersive experiences in real-life biomes and habitats (Catibog-Sinha, 2008; Clayton, 2017; Gippoliti, 2011). Finally, the use of artistic interventions by OSSEIs may provide further opportunities in disseminating complex issues (e.g. Crossick & Kaszynska, 2016).

OSSEIs work at multiple spatial scales

OSSEIs engage with and disseminate aspects of science at both global and local spatial scales; i.e. at the governmental and community level, dependent on the challenges faced by (and the needs of) society (Sutton et al., 2017). This takes place for example through natural history museums, zoos and aquaria working at a global level to protect the world's biodiversity, while simultaneously contributing to projects focused on protecting local ecosystems (Sutton et al., 2017). It is essential that the top-down global conservation strategies take full note of how essential locally driven initiatives are to the protection of biodiversity (Rodríguez et al., 2007).

The wide variety of OSSEIs in their different forms and foci provide a range of global and local orientations. Nationally based natural history museums often exhibit global topics, such as the rapid rise in atmospheric carbon dioxide, compared to locally based ecomuseums, in which the local population are involved with making decisions (Borrelli & Davis, 2012). Ecomuseums focus on cultural heritage, whereas other museums may focus on objects (Logan & Sutter, 2012). An important aim for ecomuseums is to increase the sense of place in the community, by improving the relationship on a local scale between nature and society (Davis, 1999). Zoos and aquaria have the infrastructure to disseminate global and local aspects, however these institutions attract visitors by mostly focusing on ‘mega vertebrates’ from around the world (Gippoliti, 2011).

OSSEIs have a historical consciousness

Sustainability challenges such as climate change can be expressed by showing the historical interactions that have occurred between nature and humanity, thereby re-shaping the challenge as a cultural issue, rather than one just for the scientific community (Lidström & Åberg, 2016). Not only are OSSEIs well placed to contribute to this re-shaping, but they also disseminate sustainability challenges in a manner that covers the past, present and future. For instance, zoos' living collections allow them to disseminate the past conservation history of a species, its present status and the conservation efforts required to preserve it for the future. A science centre can use its focus on technology and engineering to show how these fields are rapidly changing and what they may look like for the next generations. Natural history museums and science and technology museums are defined by their collections: three-dimensional, cultural memory banks that represent the world's past and present material diversity and adaptive intelligence (Janes & Sandell, 2019). Their collections give these museums a unique historical consciousness of sustainability problems.

The Reference Model: Synthesising Science, Policy & Practice

We return now to our main argument, that the efforts of OSSEIs to offer effective sustainability education may be constrained by the lack of an operational definition of sustainability aligning with their unique characteristics. In the preceding, we identified the features of sustainability science, of how societal stakeholders see and legitimise sustainability, and of OSSEIs' particular strengths; all of which need to be considered when designing effective sustainability education initiatives outside school. Taken together, these features circumscribe a range of opportunities for out-of-school science education that optimise the fit between sustainability knowledge, institutional conditions and constraints, and pedagogical expertise. The reference model we synthesise in the following is thus not one particular constellation of content and form, but rather a set of institutionally specific guidelines, illustrated by ideas and initiatives, that could be used by OSSEI staff members and stakeholders to optimise their sustainability education offers.

Natural History Museums

Natural history museums have a privileged relationship with the so-called historical sciences (King & Achiam, 2017), which share an epistemological orientation that crosses disciplinary boundaries. In marked contrast to what is the case for the formal education system, the transdisciplinary orientation of natural history museums is often supported by conditions in the noosphere, here exemplified by the Danish Museum Law for Natural History Museums, which states: 'the Danish natural history museums shed light on nature and its development, current environment and interplay with humans' (Ministry of Culture, 2014). These conditions provide a strong foundation for the systemic approach of sustainability science, which as noted calls for approaches that transcend traditional disciplines.

The complex nature of 'wicked' sustainability problems means that different kinds of contributions are required that span the academic and non-academic domains and lead to socially robust knowledge being produced that can grapple with these global issues. However, conversations between scientists, decision-makers and the public are challenging to frame and manage, due to the differences and degrees of specialisation each expert brings to the conversation (Garvin, 2001). Here, natural history museums have significant expertise to offer in mediating between science and society, and in making science accessible to a broad diversity of the public. Even though, as we discussed in the preceding, not all OSSEIs are as inclusive and accessible as they would like to be, still there are numerous promising examples of these trusted institutions engaging diverse publics in dialogue with experts to co-produce new and robust knowledge. Through the creation of dialogue and debate, natural history museums are presented with many opportunities for increasing inclusivity with their visitors and among local areas. The Natural History Museum London offers the opportunity for the public to meet their scientists through bi-weekly interactive talks. In addition, they run a variety of inclusive and easily accessible citizen projects, inviting the public in collecting important data to aid the museums' researchers (Natural History Museum London, n.d.).

Natural history museums have the ability to engage with and disseminate aspects of sustainability at both global and local spatial scales. By doing so, they can act as important sites for educating society about environmental issues and provide a strong sense of place, through heritage interpretation and connections with nature (McElroy, 2015; Novacek, 2008; Uzzell, 1996). Many institutions take more of a global focus in their exhibits, but link to local aspects through public talks and interactions with practitioners. Others, such as ecomuseums, place a focus purely on local aspects and cultural heritage. Simeoni & Crescenzo, (2018) discuss the proposed development of an ecomuseum in Italy, focused on the creation of a new cycle path and promoting the city's renewable energy heritage.

Finally, we have already substantiated the inherent temporal perspective of sustainability science. At the same time, the time scales involved in various sustainability problems are difficult for many of us to grasp, because they cannot be accommodated within our shared time-frame of a generation or a life-time (Held, 2001). Natural history museums have significant expertise to offer with respect to disseminating the extended timelines of geological, evolutionary, or cultural processes. Using the 2-3 billion specimens worldwide collected over the last 300 years, they provide critical historical discourse on biodiversity covering millions of years (Krishtalka & Humphrey, 2000). The 80 million specimens held at the Natural History Museum London are used in various ways, for example furthering understanding of climate change and responses by biodiversity, i.e. four species of British butterflies over the 19th and 20th centuries (Brooks et al., 2014). In this same institution, a giant tree-ring from a sequoia tree provides historical consciousness in

terms of sustainability. This 1,300-year-old object has been at the museum since 1893 and is used on the institutions' website to discuss humanity's effects on the planet, including climate change and deforestation (Pavid, n.d.).

Science and Technology Museums

Science and technology museums arose from the waves of industrialisation that swept across Europe and North America from the late 1700s. Since these beginnings, they have maintained collections of artifacts associated with industry and technology; like natural history museums, they thus represent our collective historical consciousness through their collections. Of particular relevance for sustainability education is the role of these collections as fundamental sources of cumulative technological memory at this moment in time where we seek solutions for a sustainable future (Janes & Sandell, 2019). For example, the Danish Museum of Science & Technology (Teknisk Museum) exhibits innovations that have dramatically changed the course of humanity over the past 150 years, from cars and planes to space exploration (Teknisk Museum, n.d.). Presenting the connectivity of the past and the future in this way may help counteract the deferral of sustainability and climate change as 'problems of the future' that seems to permeate public discourse (Nixon, 2017; Salazar, 2014).

With their roots in engineering and industrial design, science and technology museums are inherently transdisciplinary, and thus well positioned to engage the public in cross-cutting activities. In 2014-16, the Deutsches Museum (of science & technology) in Munich displayed an exhibition about the Anthropocene, the current geological epoch linked to the increasing influence of humanity on Earth's processes (Crutzen & Stoermer, 2000). This exhibition engaged visitors in investigating society's past, present and future through transdisciplinary themes such as urbanisation, mobility, nature, evolution, food, and human-machine interaction (Deutsches Museum, n.d.). The multiple perspectives and non-linear layout of the exhibition seemed especially well suited to the systemic and interconnected nature of the challenges of the Anthropocene (Keogh & Möllers, 2015).

Finally, just like natural history museums, science and technology museums have considerable expertise navigating the interface between science and society. As noted, a key challenge is to present and discuss sustainability in a way that does not obliterate other forms of knowledge and practices (Salazar, 2014). Science and technology museums have a special role to play here, as industrialisation has often made forceful intrusions into the homelands of indigenous people and communities, who had otherwise lived in harmony with nature (Anderson & Hadlaw, 2018; Main, 2017). Science and technology museums can build relationships with such groups to create and enrich collective understandings of the role of science,

technology and engineering in contemporary society (Alberti et al., 2018), and help audiences grapple with the emotional, cultural and physical challenges of the present crisis (Main, 2017). For instance, Museums Victoria offer education activities based on the science and technology of Aboriginal and Torres Strait Islanders that illustrate how these communities lived in ways that were sustainable for the future and the lessons that can be learned from them (Museums Victoria, 2020).

Science Centres

Over the past half century and more, science centres have maintained strong links with the experimental sciences (Oppenheimer, 1968). This association with hands-on experience and experimentation presents them with an array of potentials in disseminating sustainability challenges. As discussed, sustainability science is oriented toward real-world problems that are observed and experienced by people, e.g. the flooding of agricultural areas due to climate change (Adger, 1999) or the health risks of the haze caused by widespread use of fire to clear land (Lohman, Bickford & Sodhi, 2007). For observers of real-world problems, whether they are citizens or researchers, the immediacy of these problems is apparent. However, this immediacy can get lost in translation as sustainability problems are transposed to school classrooms or laboratories and codified in terms of the texts, graphs, tables and diagrams that characterise school science. In contrast, science centres offer experiential, affective and material approaches to their subject matter. These approaches allow visitors to transcend time and place to experience things 'possibly being so' (Achiam, Nicolaisen, & Ibsen, 2019; Achiam & Sølberg, 2017). Science centres are thus able to recreate the immediacy of sustainability problems in ways that are discernible by a broad range of visitors. The climate change exhibition KLIMA X, on view in various science centres in Europe over the past decade, presents an example of aspects of sustainability disseminated through the use of different communication modalities. The floor of KLIMA X was flooded with water to simulate sea level rise, and visitors would wade through the water, wearing wellington boots provided by the museum (Kahn, 2015). An ice block, gradually melting, was located in the middle of the exhibition, and with intervals, simulated thunder and rain would appear to illustrate meteorological disturbances. In a study of 15-16 year olds visiting the exhibition, Gorr, (2014) found significant changes in their emotional involvement in climate change, possibly because of their physical and kinaesthetic experiences in the exhibition.

The Danish science centre, Experimentarium, carried out a series of hands-on workshops, where public health experts engaged adults and children from across the socio-economic spectrum in dialogue about what exercise and movement meant for them. The workshops harnessed the hands-on expertise of the science centre, allowing children and adults to participate using different communication modalities; at the same

time, the science centre provided a comfortable and safe space for what could have been uncomfortable interactions about health. The workshops gave rise to a progressive and socially inclusive conceptualisation of health (Bønnelycke, Sandholdt & Jespersen, 2018; Bønnelycke, Sandholdt & Jespersen, 2019; Sandholdt & Achiam, 2018) that was subsequently embodied in a successful and inclusive exhibition.

Zoos and Aquaria

Zoos and aquaria, aided by their grounding within ecology and conservation biology (Gippoliti, 2011), have strong relationships with the biodiversity domain. The visual display of live animals is the main educational part of a visit to a zoo or aquaria (Churchman, 1985) and coming into contact with aspects of nature plays a vital role in environmental education (Stern, Powell, & Hill, 2014). Biome focused exhibits allow several biodiversity species to coexist in a manner closely resembling the habitats on Earth. For instance, the Rainforest exhibit at Copenhagen Zoo is an indoor multi-sensory experience, with a high level of humidity and thick mass of vegetation. In comparison, the South Pole Spectacular exhibit at Ocean Park Hong Kong provides a chilly and immersive experience, with the chance to closely interact with three different penguin species. Both exhibits have educational programmes and activities focused on associated sustainability challenges, including deforestation and climate change respectively.

Research has shown a link between society's actions towards climate change and feeling connected to biodiversity in zoos (Clayton et al., 2014). These institutions have an opportunity to increase the feeling of sense of place among their visitors. Odense Zoo in Denmark recently installed an immersive tree-top exhibit focused on local nature (Odense Zoo, n.d.). Bejjani (2018) found a greater sense of place among visitors to zoos that focused more on local species, as well as among local zoo visitors. Research has shown that a sense of place can play an important role in the ability of local populations to adapt to changing ecosystems, such as from climate change (e.g. Adger et al., 2013). Through memories and experiences, an individual or group can develop an emotional connection to a particular setting or environment (Masterson et al., 2017), creating a personal feeling of connection to the world around you.

Implications for Sustainability Education

In this study, we have substantiated and qualified the claim that OSSEIs have specialised roles to play in promoting global sustainability. It has already been established that to ensure sustainability education is successful, transformative pedagogical innovations are required that are inter/transdisciplinary, place-based and experiential (Brundiers, Wiek, & Redman, 2010; Sipos, Battisti, & Grimm, 2008). However, the institutionally specific reference model we present here goes further in arguing and illustrating the potentials for sustainability education that are singular to different kinds of OSSEIs, and that optimise the fit between

knowledge, pedagogy and institution. In the following, we discuss the implications of our findings for sustainability education.

First, we have taken an institutional and content specific approach because previous research seems to have been focused first and foremost on offering proof of concept *that* educational institutions can indeed provide sustainability education programmes, rather than getting into more detailed studies of *what* each kind of institution or setting can specifically offer. For instance, in a review of climate change education research, Monroe et al., (2019) group together school classrooms, botanical gardens, summer programmes, exhibits, and other settings to identify effective strategies. Kemmis & Mutton, (2012) characterise exemplary practices in education for sustainability across educational, governmental, and community settings. While these authors discuss the importance of *place* and *materiality* for sustainability education, the exemplary practices are formulated in terms that are not specific to content or setting, e.g. sayings, doings and relations. Green & Somerville, (2015) find that across eight primary schools, good practices included prompting creative processes, partnerships with the local community, connections with local places, and the materiality of school grounds. Again, although this study acknowledges the importance of place and materiality, the good practices themselves seem to remain non-specific to sustainability content or setting. Finally, Janes, (2015:5) discusses how museums can and should confront climate change, based on their 'historical consciousness, sense of place, long-term stewardship, knowledge base, public accessibility, and unprecedented public trust', yet these are features that cut across museums of all disciplines.

There are many good reasons for studies such as these to deal with overarching features of sustainability education, rather than delving into content-specific and institution-specific considerations (e.g. Rasmussen, 2017). One reason might be, as we hinted in the preceding, that it has been necessary for the educational research community to provide a general proof of concept of educational institutions' ability to carry out sustainability education, before more detailed studies could be prioritised (Katiliūtė, Daunorienė, & Katkutė, 2014). Another reason might be that because sustainability remains rather broad and ill-defined for education, both inside and outside schools (Brown, 2019; Jickling & Wals, 2008), the tasks of both sustainability educators and researchers are difficult to concretise. However, we believe the trade-off between the broad generalisability of a study, on one hand, and its specific implications for practice, on the other, is worth making. Accordingly, we have sought to describe content-specific and institution-specific potentials for sustainability education.

The SDGs are the strongest directive yet seen for sustainability education policy and practice (Sterling et al., 2017), and simultaneously shape the foci of specialised organisations and individual institutions and constrain

it to the 17 themes involved. Even so, progress towards achieving the goals has been slow, with the majority of the 169 targets off track. In fact, the goals related to biodiversity loss, climate change and inequality are showing negative progress (Messerli et al., 2019). Sutton et al., (2017) argue that museums have the capacity to contribute to all 17 SDGs, in particular SDG 17 (Partnerships for the Goals), while McGhie, (2019) has produced a comprehensive guide aiding museums in embracing the SDGs, and Chung, Tyan, & Lee, (2019) exemplify how museums can positively add to SDG progress. Indeed, the recent focus of attention from specialised organisations (e.g. ICOM, SCWS and WAZA) on the goals indicates that they will play an increasingly important part in shaping sustainability education in out-of-school practice. However, it must also be considered for what reasons these organisations and their members are absorbing them into their policies and practices. This focus could be based on a drive to maintain relevance among visitors and potential funders, or perhaps a response to bottom-up pressure instigated by practitioners. Further, the SDGs might be viewed by OSSEIs as a recognisable platform to gain quick and easy answers for sustainability education that obviates the need for comprehensive systematic reviews of dissemination policies and practices. These questions remain outstanding.

Finally, an important issue related to sustainability education, that admittedly is beyond the scope of the argument presented here, is that of institutional ideology. Sustainability education has been discussed in terms of activism and advocacy (e.g. Rodegher & Freeman, 2019); approaches that many OSSEIs avoid in an attempt to remain neutral (e.g. Sforzi et al., 2018). This avoidance is perhaps what is manifested when some OSSEIs consciously and explicitly steer clear of the SDGs, and instead focus on providing basic scientific knowledge related to sustainability that fits with their institutional strengths. Although we understand that OSSEIs do not wish to jeopardise their position as highly trusted and impartial, we would argue (alongside others, e.g. Evans et al., 2020; Janes, 2009; Janes, 2015; Janes & Grattan, 2019; Rodegher & Freeman, 2019) that simply providing knowledge about science related to sustainability is not sufficient; it is, in effect, engaging the public in the science *for* sustainability, rather than science *of* sustainability (cf. Spangenberg, 2011). Accordingly, we end our discussion by stating that we not only think it is essential for OSSEIs to use their unique potentials and institutional specificities to fully embrace sustainability education, we also think that incorporating related policies and practices into OSSEIs' external and internal workings is all-important. By doing so, these globally distributed and trusted sites of out-of-school science education can lead from the front as catalysts for a sustainable future.

In conclusion, we acknowledge the many challenges faced by specialised organisations, individual institutions and their practitioners. We hope that our suggestions can stimulate discussion, debate and research within out-of-school science education and related fields, spurring progress towards the operationalisation of

sustainability for practice and ultimately leading to more systematic and effective contributions to global sustainability.

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We now move from Paper One to Paper Two

9.2 Paper Two

The Scope and Status of Sustainability Education in Out-of-School Settings across Denmark

Evans, (in press)

Abstract

Denmark has a strong foundation in terms of sustainability, making the country an interesting backdrop for studying how the overarching sustainability agenda has shaped education practice. This study investigates the scope and status of sustainability education targeted at grade 4-6 students in Danish out-of-school science education institutions, such as natural history museums, science and technology museums, science centres, zoos and aquaria. First, a desktop review took place to map educational programmes with sustainability content. Second, five representative programmes were selected for further study. Thematic analysis of observation field notes and interviews with educators and teachers yielded four themes that collectively defined the sustainability programmes: institution, formal education, content and pedagogy. The final sections of the paper contextualise these themes, and discuss their implications for sustainability education in out-of-school practice. The study concludes by offering reflections on constructive future pathways for sustainability education.

Introduction

Denmark has a strong foundation in terms of sustainability. The 2020 Sustainable Development Report, measuring nations' progress towards the Sustainable Development Goals (SDGs), ranks Denmark in second place out of 166 countries (Sachs et al., 2020). The country is a global leader in wind power (Wang et al., 2017) and well known for having a social welfare system supported by high taxation (Breiting & Wickenberg, 2010). Important Danish societal characteristics include a focus on collective rather than individual interests, as well as the 'preservation of the public good' (Wals, 2010, p. 147). In 2009, the capital city of Copenhagen hosted the annual climate change summit (COP 15) (Breiting & Wickenberg, 2010) and is attempting to become the world's first carbon neutral city by 2025 (Birnbaum, 2019). Copenhill, a waste to energy power plant providing energy for tens of thousands of people, doubles as a recreational site all year round through a café, ski-slope and hiking trails (Nordestgaard & Arndt, 2019). Recent extreme weather events in Denmark, such as the abnormally hot summer of 2018, have shifted political, business and citizen focus further towards sustainability. Awareness and concern is growing among the younger generation of eco-citizens (cf. Heggen et al., 2019) and youth climate strikes have received large attendances across the country. In 1993, the Danish government encouraged all schools to add in environmental issues to their curricula (Mogensen & Nielsen, 2001). Today, sustainability forms a part of the Danish school curriculum in many subjects, including the sciences, technology, social studies, history, geography, food literacy and fine art (Simovska & Prøsch, 2016).

Denmark's positive strides towards a sustainable future make the country an interesting backdrop for studying how the overarching sustainability agenda has shaped education practice. The Danish government created an Action Plan for the SDGs in 2017 (Danish Government, 2017), which acknowledges the important role of stakeholders and civil societal actors in moving towards a sustainable future. Denmark's range of out-of-school opportunities form an important component of this Plan. However, the 2020 Sustainable Development Report labels goal 4, Quality Education, as stagnating in Denmark, while all other SDGs are progressing. This result is due to a decrease in the underachievers and resilience of students in science (Sachs et al., 2020). In addition, Danish sustainability education has fallen behind Sweden, due to greater focus on enhancing science education (Breiting & Wickenberg, 2010).

As indicated above, sustainability plays an important role in the formal school system in Denmark (e.g. Simovska & Prøsch, 2016). In contrast, research has identified the special potential of out-of-school science education institutions (OSSEIs), such as natural history museums, science and technology museums, science centres, zoos and aquaria, for preparing citizens for a sustainable future (e.g. Berg et al., 2021; Clayton, 2017; Evans & Achiam, 2021; Janes & Grattan, 2019; Patrick et al., 2007). These institutions offer a highly trusted,

educational and experiential experience suitable for a wide-range of ages, across both political and societal spectrums (Cameron, Hodge & Salazar, 2013; Clayton, 2017). OSSEIs are located throughout all regions of Denmark and have different areas of expertise and institutional conditions. Many Danish OSSEIs offer a range of school programmes for visiting classes, with content and activities drawing on their expertise and institutional conditions. Formats range from on-site educational programmes to outreach programmes and visits to off-site locations, such as recycling centres.

The strong foundation of sustainability within Danish society, combined with a passionate and engaged younger generation and the range of out-of-school opportunities, present a robust platform for sustainability education. In turn, this may prompt a range (and depth) of initiatives, shaped by the strengths and expertise of Denmark's OSSEIs. The aim of the study is to investigate the scope and status of sustainability education in OSSEIs across Denmark. This mapping research can play an important role in furthering understanding of the current situation of out-of-school sustainability practice in Denmark. It will highlight the challenges faced and potentially lead to an indication of (and the sharing of) best practices, and finally, indicate future areas for improvement.

Methods

In this study, quantitative and qualitative methods were used to investigate the scope and status of sustainability education. The data collection took place in two main phases, first the scope (quantitative) involving a review, search for sustainability content and then selection, followed by the status (qualitative) in the form of interviews and observations (Figure 1).

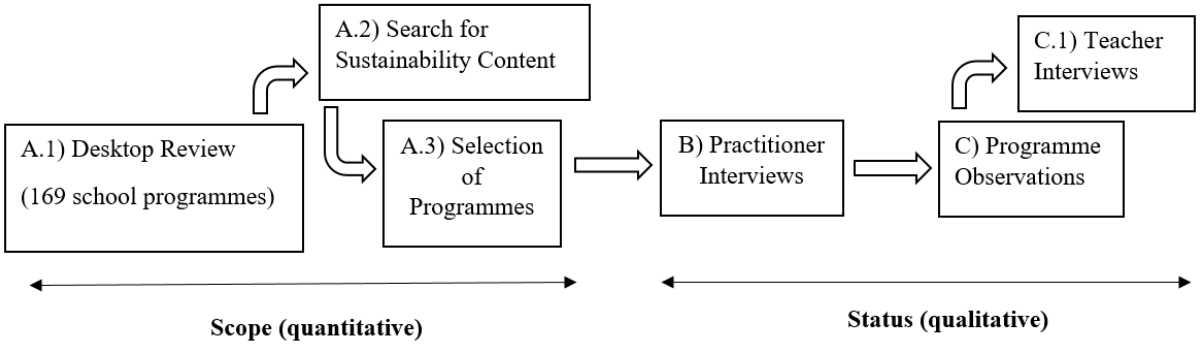

Figure 1. The three stages (A-C) in mapping the scope and status of sustainability education in OSSEIs across Denmark. The first step (A.1) identified 169 school programmes targeted at grade 4-6.

A focus is placed on school programmes designed for visiting classes between the ages of 10-12 years old (grade 4-6, also known as the intermediate stage in Danish education). This age range was chosen because

students aged 10 often display a positive attitude and interest towards science (i.e. Archer et al., 2010), with no distinction found between genders (Murphy & Beggs, 2005). Attitudes and interests are often fully developed by the age of 14, and motivation dramatically decreases throughout the teenage years (Archer et al., 2010).

To assess the scope, that is, the number of sustainability programmes offered, and the range of topics addressed, a quantitative review of school programmes offered by Danish OSSEIs was carried out (Figure 1). The quantitative data then formed the basis to select representative programmes. Those selected formed the basis for a more in-depth, qualitative investigation of the status, using thematic analysis (cf. Braun & Clarke, 2006).

A.1) Desktop Review

Research took place in February 2020, with a second confirming review in September updating the data set. Firstly, school programmes targeted at grade 4-6 were searched for, using information found on the institutions' own websites. OSSEIs included were affiliated with the natural sciences and offering natural science education programmes. Programmes were included if led by an OSSEI practitioner and held on-site at the institution. Programmes targeted at a broad age-range (i.e. grade 1-10) that incorporated grades 4-6, as well as programmes targeting at least one of grade 4, 5 or 6 (i.e. grade 1-4 or just grade 6), were also included.

In the desktop review, a preliminary list of 169 school programmes across 23 OSSEIs were identified. These 23 OSSEIs represented five well-known types of OSSEIs, including natural history museums, science & technology museums, science centres, zoos and aquaria. More than two thirds (or 116 of 169) of the programmes were offered by either a zoo or aquarium (Table 1).

Table 1. The number of institutions and school programmes for each type of OSSEI targeted at grades 4-6.

Type of OSSEI	Number of Institutions	Number of School Programmes
Natural history museum	5	33
Science and technology museum	2	12
Science centre	2	8
Zoo	8	64
Aquarium	6	52
Total	23	169

As the 23 OSSEIs were categorised, occasionally it was difficult to distinguish between the five types of OSSEIs, based on their 'traditional' characteristics (cf. Cameron, Hodge & Salazar, 2013). On the other hand, these characteristics are important, due to the influence they have on sustainability education programs.

Data collection worked on the assumptions of natural history museums and science and technology museums being predominantly collection based, considered science centres to be focused on providing kinaesthetic, hands-on experiences (Schwan, Grajal & Lewalter, 2014), and zoos and aquaria basing their work on live biodiversity collections and conservation intentions (McCalman, 2017).

A.2) Criteria for Sustainability Content in Programmes

Using information provided on institutions' websites, the 169 school programmes were analysed for sustainability content, and involved two criteria for inclusion. Firstly, programmes were included that explicitly described their content in terms of humanity's impact on the planet. Secondly, this content was deemed to play a major role in the session's focus and activities. This process led to eight OSSEIs removed from the sample, due to having no sustainability programmes targeted at grades 4-6. Many programmes were excluded immediately due to their topics having no clear or obvious links to sustainability. Examples include programmes carrying out dissections focused on anatomy, using mathematics to discuss an animal's diet, and using artistic methods to draw biodiversity. After careful deliberation, further programmes were excluded due to having no explicit connections to sustainability. Examples of this are zoos and aquaria programmes disseminating a species' biological traits, such as anatomy, adaptations and diet, but with no explicit connections to i.e. a changing climate, pollution, loss of habitat or poaching.

A few programmes contained sustainability content through a list of specific elements of the Danish school curriculum that the session targeted. For example, the programme Wildlife of The Winter Forest, offered by Aqua Aquarium & Animal Park, disseminates animals' biological traits (i.e. adaptations to winter). One of the targeted curriculum elements is 'students will have knowledge of the human impact on natural areas over time'. Without observing the programme, it could not be ascertained to what extent this particular curriculum element played a role in the session. Accordingly, the programme was excluded based on the assessment that the programme focus and activities lacked sufficiently explicit connections to sustainability.

Next, sustainability topics were identified that characterized the programmes, drawing on sustainability research literature, the 17 SDGs, and their associated targets.

A.3) Selection of Samples of Programmes

A smaller sample of sustainability programmes were selected, representing the diversity of geographical location, type of OSSEI and sustainability topic. This smaller sample formed the basis for investigating the status of sustainability education in OSSEIs across Denmark, using interviews and observations.

B) Practitioner Interviews

Five semi-structured interviews were carried out with practitioners, i.e. school programme directors or main educators, associated with the programmes selected, with one representative from each of the five types of OSSEIs. The interviews took place in English between September to December 2020. As this part of the research aimed to investigate the status of sustainability education, interview questions were targeted at providing a more detailed understanding of programme content, and how the institution's specific subject area, pedagogy and societal role influenced the dissemination of sustainability. Freehand notes were taken throughout each interview. Due to COVID-19, only one interview could take place face-to-face, meaning three interviews were carried out by phone and one by Zoom video. The variety of different communication methods potentially had an impact on how the different interviewees responded to the questions. For example, prior to the single face-to-face meeting, the researcher and interviewee spent a whole morning together at the institution to first observe the relevant selected programme. This additional time together in comparison to the other interviews may have affected the data collected.

C.1) Observations of Programmes

Due to COVID-19, three programmes were observed, with an additional interview carried out for the two missed programmes. With this part of the research once again aimed at investigating the status of sustainability education, observations provided a more in-depth understanding of the scientific content of the programme and pedagogy used in exercises, building upon the interview data. Most importantly, observations allowed for the following of student interactions, such as how they approached a problem solving exercise and their general interest in the topics. The researcher introduced themselves at the beginning of every observation to explain why there was an additional adult present. Field notes were taken throughout each observation and the researcher carefully positioned themselves to minimise disruption to students, teachers and educators.

C.2) Teacher Interviews

Semi-structured interviews were carried out with a teacher attending the session with their school class. Four teacher interviews took place in total, with two from different classes attending the same programme on the same day, but at different times. Interview questions aimed to clarify the reasons for participating in the program, the pre-session work carried out and the use of the experience post-session.

Data Analysis

Researcher's field notes for the four teacher interviews and three observations were analysed using thematic analysis (cf. Braun & Clarke, 2006). Main themes were identified, using both inductive (bottom-up) and

deductive approaches (top-down), using the six stages of Braun & Clarke, (2006). The first stage involved re-reading the data set to become familiarised with it. For the second stage, initial codes were created by looking across the data set, developing these codes into themes and sub-themes during the third stage. Decisions were made on sub-themes and individual codes by deciding what was foreground and background. Themes were reviewed in the fourth stage, and consequentially led to some sub-themes moved to create a more coherent analysis. The fifth stage involved the re-defining of themes, and focusing on the overall narrative. Finally, the analysis was written up, and the themes and corresponding sub-themes are presented in the following sections.

Results: The Scope of Sustainability Education

A total of 34 school programmes were identified to include sustainability content, making up approximately 20% (34 out of 169) of the reviewed programmes targeted at grade 4-6 in Danish OSSEIs. These 34 programmes were offered by 15 OSSEIs, meaning close to two-thirds (15 out of 23) of OSSEIs reviewed offering programmes containing sustainability content (Table 2). All five types of OSSEIs offer at least two programmes, with zoos and aquaria again offering over two-thirds (or 23 of 34). The 15 OSSEIs are located across Denmark, representing Zealand (eastern Denmark), Funen (central Denmark) and Jutland (western Denmark) (Figure 2).

Table 2. The number of institutions and school programmes for each type of OSSEI targeted at grades 4-6 containing sustainability content.

Type of OSSEI	Number of Institutions	Number of School Programmes
Natural history museum	2	3
Science and technology museum	2	2
Science centre	1	6
Zoo	5	14
Aquarium	5	9
Total	15	34

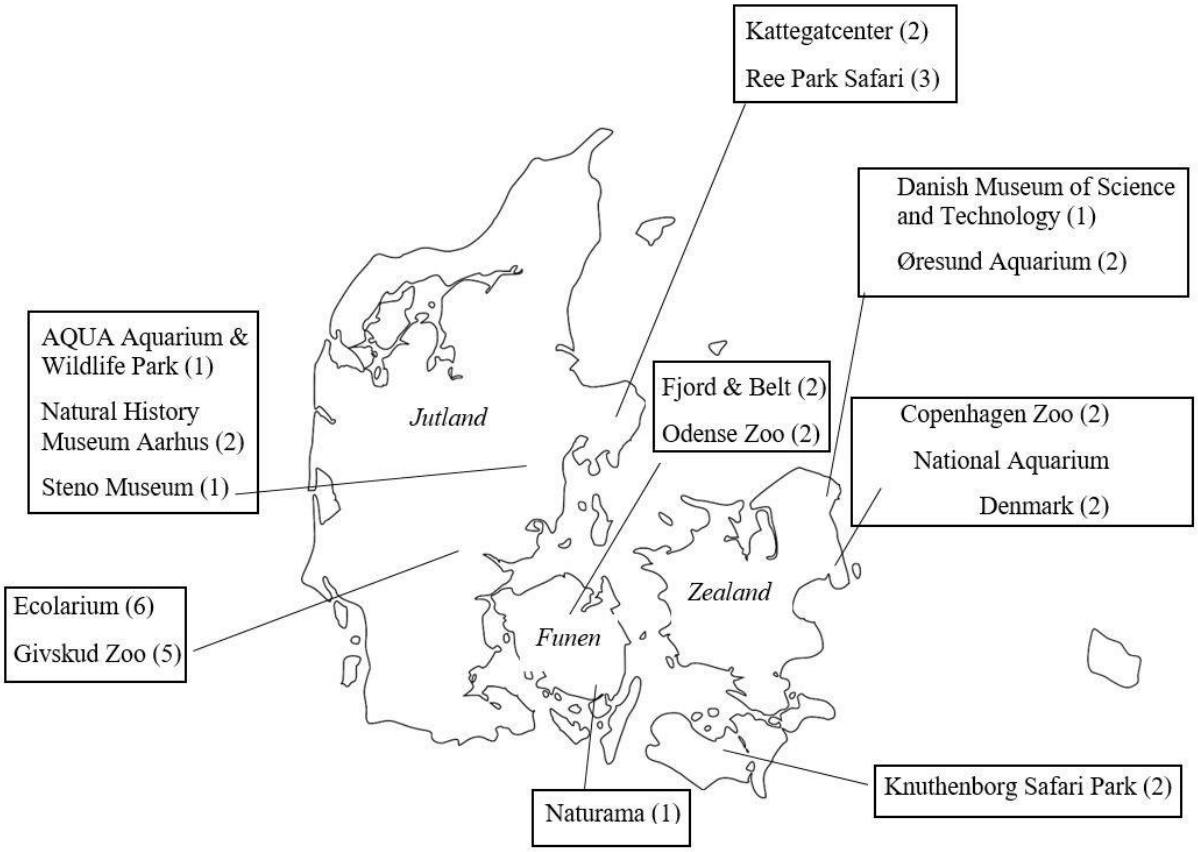

Figure 2. A map of Denmark showing the locations of the 15 OSSEIs containing sustainability content and the number of programmes they offer.

Sustainability Topics

The 34 school programs address six sustainability topics. They are as follows (with associated SDG targets): biodiversity conservation (15.5), climate change (13.3), food (i.e. a sustainable diet – no SDG target), plastic pollution (SDG 14.1), the SDGs, and technology (9.4). Three outlier programmes on evolution, a lake survey and a quiz, respectively, were deemed as not fitting into any of the six above, leading to the creation of an 'Other' topic.

The most frequent sustainability topic was biodiversity conservation, present in over two-thirds (or 24 of 34) of school programmes, offered by natural history museums, zoos and aquaria. Climate change was the second most frequent sustainability topic, forming a part of almost one quarter (or 8 of 34) of school programmes, with all five types of OSSEIs offering programmes on this topic. Plastic pollution was the third most frequent topic, found in almost one fifth (or 6 of 34) of programmes and offered by science centres and aquaria. Technology appeared in 4 of 34 (or 12%) of programmes, offered by science and technology museums and science centres. The SDGs as a central topic of the session (rather than just briefly introduced or used in an exercise) was found in 3 of 34 (or 9%) and offered by natural history museums and zoos. Finally, food appeared in 2 of 34 (or 6%) programmes, offered by a science centre and an aquarium (Figure 3). The

highest occurrence of topics appearing together is biodiversity conservation and climate change, in just under one sixth (or 6 of 34) of programmes, offered by natural history museums, zoos and aquaria.

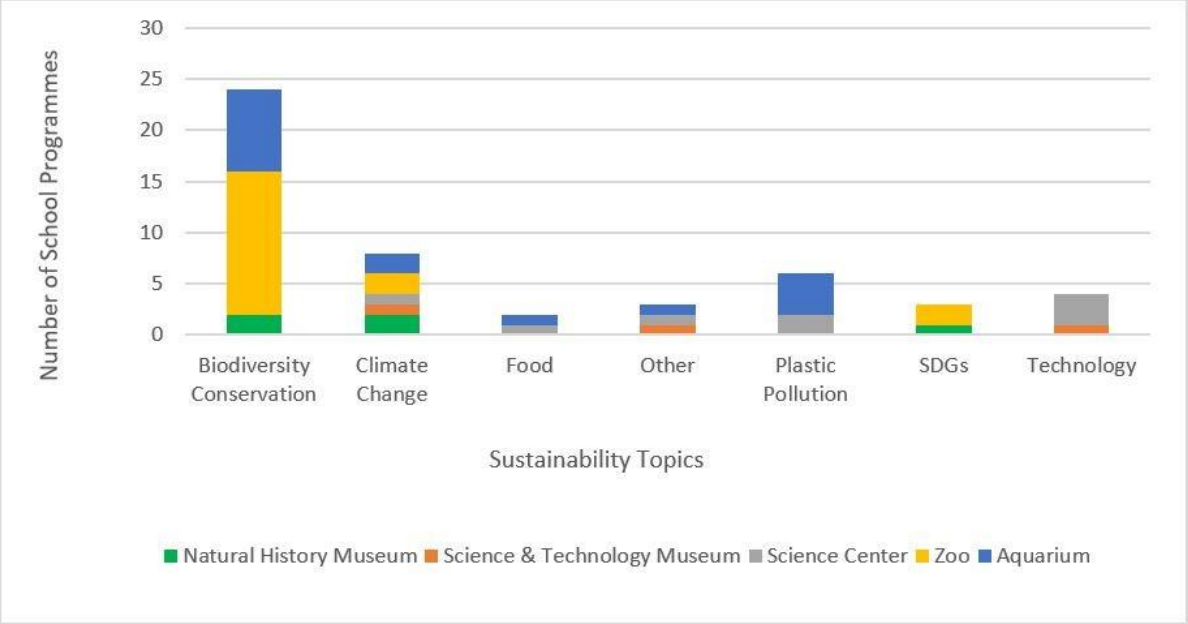

Figure 3. The breakdown of sustainability topics in 34 school programmes targeted at grade 4-6, offered by fifteen OSSEIs across Denmark. A programme could address more than one sustainability topic.

Selection of Programmes

Programmes selected for qualitative analysis represent the five types of OSSEIs, the five most frequent sustainability topics (biodiversity conservation, climate change, plastic pollution, the SDGs and technology) and a geographical spread across Denmark. In addition, the selected programmes have a range of target age-ranges and session lengths (Table 3).

Table 3. An overview of the five school programmes selected to represent the status of sustainability education, analysed by interviews with practitioners and teachers, and observations.

Type of OSSEI	Name of Institution	Town and Region	School Programme	Target Age Range	Session Length (minutes)	Sustainability Topic(s)
Natural history museum	Natural History Museum Aarhus	Aarhus, Jutland	United Nations Sustainable Development Goals – Our World	Grade 1-10	60	SDGs
Science & technology museum	Danish Museum of Science & Technology	Helsingør, Zealand	Inventions	Grade 4-6	90	Technology
Science centre	Ecolarium	Vejle, Jutland	Robot Programmer	Grade 4-10	150	Technology, plastic pollution
Zoo	Odense Zoo	Odense, Funen	Threatened Animals	Grade 4-10	60	Biodiversity conservation
Aquarium	National Aquarium Denmark	Copenhagen, Zealand	The Sea Sweats and Appetizing Waste	Grade 4-6	60	Biodiversity conservation, climate change, plastic pollution

Results: The Status of Sustainability Education

Four themes emerged from thematic analysis of practitioner interviews, teacher interviews and programme observations: institution, formal education, content and pedagogy (Figure 4). Twelve sub-themes were identified within these themes, presented in the following. The theme 'content' contains two sub-themes that emerged deductively from earlier research: spatial scale and inclusion (Evans & Achiam, 2021).

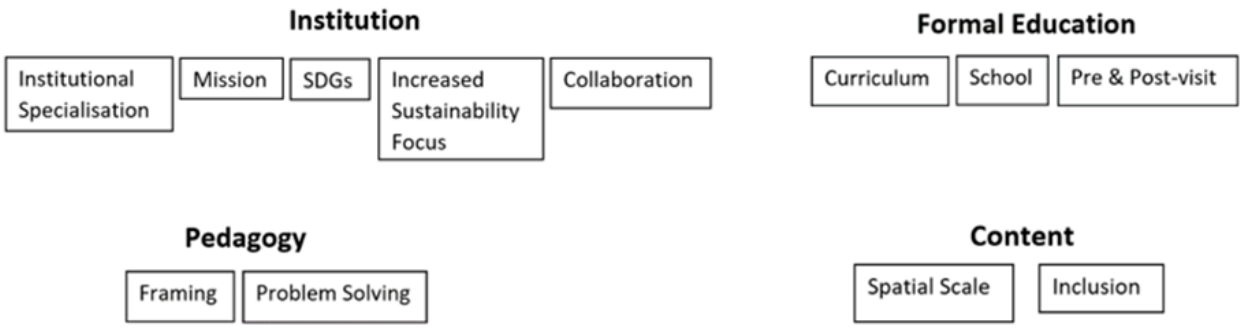

Figure 4. A thematic map representing the four themes and corresponding 12 sub-themes.

Institution

The theme of institution refers to the ways in which the specific type of institution (i.e. natural history museum, or zoo) interacts with the design or implementation of the programme. The reader will recall that the researcher found five types of OSSEIs of interest for this study. The following five sub-themes were identified: institutional specialisation, mission, sustainability policy and institutional practice (in terms of the SDGs), increased sustainability focus and collaboration.

Institutional specialisation

Institutional conditions constrain practice, and define the areas of strength and expertise available for sustainability education (Evans & Achiam, 2021). All interviewed practitioners emphasised the specialisation (i.e. unique conditions and focus) of their institutions, and how this allowed them to offer experiences for visiting students not found in schools or other educational sites. Practitioners from Natural History Museum Aarhus and Danish Museum of Science & Technology emphasised the importance of their collections in engaging with sustainability, for instance using the historical consciousness imparted by their collections to disseminate the future. Practitioners from Natural History Museum Aarhus and Odense Zoo discussed how their specimens and live collections provide a different perspective to nature, while the practitioner of Ecolarium focused on experiential aspects, such as engaging senses and creating emotion. The zoo and aquaria practitioners focused on their live animals in terms of the special feelings they prompt among learners, as well as the high level of nature expertise among staff. The practitioner of The Blue Planet viewed their close proximity to the sea as an important component in their education, while the practitioner of Odense Zoo emphasised the importance of visitors viewing animals not normally seen. Finally, institutional specialisation played important roles in the exercises of the observed programmes. For example, collections at Danish Museum of Science & Technology were presented as inventions (and used in exercises), while exercises at The Blue Planet (or National Aquarium Denmark) involved two fish species (common goby and coral shark), and a brine shrimp.

Mission

The missions of OSSEIs play an important role in framing their education practices (Patrick et al., 2007). Indeed, in four of the practitioner interviews carried out here, the institutional mission seemed to significantly influence sustainability practice. For example, Natural History Museum Aarhus works to ‘do research within natural sciences and to promote knowledge of scientific research’ (Naturhistorisk Museum, n.d.), and the practitioner made connections to this by discussing how their research and practice works to inspire students to gain knowledge of science and nature. A similar ambition was observed in the interview

with the practitioner from the Danish Museum of Science and Technology, who invoked the museum's mission to 'inspire creativity and innovation' (Teknisk Museum, 2021) in their discussion of how they have a moral obligation to make children interested in how to be involved in changing the world. The practitioner of Ecolarium placed an emphasis on their role of acting as translators of different scientific topics, which connects to their sustainability focused mission of 'enabling guests to make sustainable choices through knowledge, experiences and active learning' (Økolariet, n.d. a). The same practitioner went further and emphasised the role of students in acting as conduits of sustainability education to others (cf. Lawson et al., 2018, 2019):

> Students visit with school and become ambassadors. They tell their parents and grandparents, then come back to visit as a family. [The] younger the students, the more likely this is to happen (Practitioner, Ecolarium).

Finally, Odense Zoo's mission is 'to engage in serious animal and nature conservation and research, reflected by the practitioner focusing on saving animals and nature (Odense Zoo, n.d.).

Sustainability Policy and Institutional Practice: The SDGs

The SDGs play a prominent role in sustainability policy (Sterling et al., 2017), and so unsurprisingly, they appeared regularly in practitioner interviews when discussing sustainability practice. However, practitioners expressed differences in how their institutions approach the SDGs; being explicit in three of the selected programmes and not mentioned in two. The practitioner of Natural History Museum Aarhus explained that pressure from leadership had prompted a greater focus on the SDGs within practice, leading to the creation of an exhibition and school programme (*United Nations Sustainable Development Goals – Our World*). Ecolarium practice focuses on sustainability, reflected by the inclusion of the SDGs in all exhibitions and school programmes. Their website has a page titled 'what are the United Nations Sustainable Development Goals?', with interactive videos and links for further information (Økolariet, n.d. b). In the observed program *Inventions* at Danish Museum of Science and Technology, the SDGs form part of the introductory presentation, framing the concept of sustainability and the global challenges of relevance for the session, i.e. plastic pollution and technological solutions. In comparison, both zoo and aquaria practitioners expressed how the SDGs were unsuited for their institutional practice. The practitioner of The Blue Planet described the SDGs as being too large-scale for their practice, and as a 'wish-list' that they '[implicitly] aim to connect with the real world, via methods and basic scientific knowledge, for example through physiology and biology' (Practitioner, The Blue Planet). Further constraints expressed by zoo and aquaria practitioners included the complexity of the SDGs for younger students, the short amount of time allotted for providing a fun and

educational school program, and issues relating to marketing (and space), such as already having a large amount of signage informing visitors of different topics and campaigns.

Increased Sustainability Focus

The importance of sustainability for society is growing. The practitioner from Ecolarium indicated that their increasing visitor numbers (doubled over the last decade) were evidence of this growing importance. Another indication of an increased interest in sustainability, discussed by the practitioner of The Blue Planet Denmark, is the large number of students contacting the institution every year with questions regarding what they can do to save the world. Generally, all OSSEI practitioners emphasised an increasing focus on sustainability in their external practices, i.e. exhibitions and programmes. The practitioner of Natural History Museum Aarhus explained how their practice has changed to focus more on science, (i.e. through incorporating the SDGs into practice), compared to the previous foci of animals and nature. The practitioner of Danish Museum of Science and Technology discussed how the institution is evolving to incorporate more present-day themes into practice (i.e. by incorporating the SDGs into the school programme *Inventions*), while at the same time maintaining their embodied and more traditional historical consciousness. The practitioner of Ecolarium discussed the process of updating content of their school program, *Robot Programmer*, in order to contain elements of sustainability practice:

> Over past 12 years, the programme has changed from being just programming robots and about those used to explore the surface of Mars, to now be focused on sustainability topics like plastic pollution and how this issue can be solved using robots, i.e. the large ocean plastic gyres (Practitioner, Ecolarium).

The practitioner of Odense Zoo was the only interviewee to mention a greater internal focus on sustainability, through the banning of plastic straws and all products containing palm oil.

Collaboration

The transdisciplinary nature of sustainability science calls for participatory processes with the integration of different forms of knowledge involving stakeholders across society (Craps, 2019). Two practitioners emphasised examples of collaborating with stakeholders. Danish Museum of Science & Technology regularly works with universities and local companies, ensuring that museum practice stays up to date with a fast changing modern society. The practitioner of Ecolarium acknowledged the role of outside experts, and that the majority of their staff are not scientists. For example, a robotics professor at a Danish university was involved in developing the school programme, *Robot Programmer*.

Formal Education

The theme of formal education contained the three sub-themes of curriculum, school and pre & post visit.

Curriculum

The curriculum is an important part of the formal education system, and as discussed, sustainability forms an important part of the Danish school curriculum. Four practitioners emphasised the influence of the school curriculum in designing their programmes. The practitioner of Natural History Museum Aarhus spoke of the need to follow the curriculum, by highlighting an increasing focus within the Danish curriculum on the SDGs (reflected by the institution's incorporation of the SDGs into practice). The practitioner of Odense Zoo discussed the speed at which the curriculum changes. In addition, four practitioners emphasised the importance in providing an appealing proposition for teachers, and two teachers highlighted curriculum links as an important reason for booking the programme.

School

Sustainability education, such as on climate change, usually occurs within the school classroom environment (Sellmann & Bogner, 2013). Teachers gave many reasons (in addition to curriculum links) for booking the programme. These included the close proximity to school, free entry, the fun and entertaining experiences for students, the benefit of having someone else teaching the students, and students' enjoyment of being out of school. The practitioner of Odense Zoo discussed the challenges faced by teachers in educating their students on climate change, and the role their institution can play:

> Climate change is a part of what teachers are required to teach children. It is a very difficult topic for teachers - a dark subject, sad and worrying. Teachers often run away from it, so it is much easier to hand it over to the zoo to do instead (Practitioner, Odense Zoo).

In addition, the same practitioner highlighted the school classroom as being a more suitable environment for disseminating the SDGs to students, stating that the 'SDGs are a teacher's job on a wet Thursday afternoon – to show how the world is working together' (Practitioner, Odense Zoo).

Pre & Post Visit

It is important to briefly acknowledge the potential educational limitations of a school programme, such as their often short duration and one-off instance. This in turn places greater emphasis on the pre and post visit work carried out by the teachers and students. In the interviews with the teachers, a broad variation of ways to prepare students for the education programs was noted, as well as a variety of ways to follow up on the

visit. Pre-visit work ranged from no preparation, a brief discussion on expected behaviour, watching a relevant film, to finally, a 'facts day' covering the focal problem (i.e. plastic pollution) and the sources of it (i.e. plastic bags). Furthermore, school location determined whether the class stayed to explore the institution after the programme, or headed straight back to school. The majority of observed classes had travelled far by bus, meaning the trip was a half or full day visit, and so spent time walking around the institution. Looking longer-term, all observed classes planned to refer back to the programme when covering related topics, such as robots or plastic pollution in the classroom. One class planned to carry out a project on robots; however, sustainability was not a compulsory element. Another class planned to build upon the programme *The Sea Sweats and Plastic Fantastic*, by using art and music to encourage pro-environmental behaviour in the local area.

> The class is making a whale sculpture to be moved around the city while they pick up rubbish. The sculpture will have QR codes for further information. The class will sing the famous Danish song called 'Hvalen Hvalborg' (a song about whales created by the Danish pop group, Shu-bi-dua) while walking around the city (Teacher attending the program *The Sea Sweats and Plastic Fantastic* at the Blue Planet).

Content

The theme of content contained the two sub-themes of spatial scale and inclusion.

Spatial Scale

Sustainability science and policy work at both the global and local scales (Evans & Achiam, 2021). In addition to a strong global component, all five selected programs address the local spatial scale in different ways. *Inventions* starts by discussing the work of Jacob Ellehammer, a famous Danish inventor, with his aircraft hanging above the students (Figure 5).

Figure 5. An educator at the Danish Museum of Science and Technology teaching students about the inventions of Jacob Ellehammer, a famous Danish inventor.

A treetop walkway, focused on Danish nature, forms part of *Threatened Animals*. The common goby, used in The Sea Sweats, inhabits Danish waters and is often found by students when rock pooling. *Robot Programmer* ends with showing a video of Henrik Sharfe, a Danish professor who designed a look-alike robot. The practitioner of Ecolarium emphasised the focus within their exhibitions on local areas (visited by school classes towards the end of the program):

> Many of Ecolarium's exhibitions are about local areas, e.g. Vejle fjord and Vejle river valley, with links to environmental issues affecting them. Local students can relate to them, and they can compare them to other locations found across Denmark (Practitioner, Ecolarium).

Another way to address the local scale is pro-environmental behaviour. Four programmes focus on individual actions students can realistically engage in within their local area to make a positive difference. Conversely, *United Nations Sustainable Development Goals – Our World* attempts to operationalise pro-environmental behaviour within a more globally orientated framework of sustainability, by asking students to choose the five goals most important to their own lives.

Inclusion

OSSEIs are increasingly working to become more inclusive and accessible (e.g. Achiam & Sølberg, 2017); at the same time, equality is a central element of sustainability. Two of the practitioner interviews emphasised aspects of inclusion in terms of age and gender. The practitioner of Danish Museum of Science & Technology referred to a discussion that takes place with students as part of the program *Inventions*, on the appearance of Jacob Ellehammer:

> He looks like a classic inventor…old man, beard… but not all inventors look like this these days – everybody can do it [invent], any gender (Practitioner, Danish Museum of Science and Technology).

The practitioner of Ecolarium presented a further example of inclusion, when discussing the development of the programme *Robot Programmer*. The practitioner explained how the international study on the Relevance of Science Education (ROSE) (see Sjøberg & Schreiner, 2005) found robotics to be relevant for boys and girls. This research finding led to Ecolarium designing a robotics exhibition and corresponding school programme.

Pedagogy

In this context, pedagogy refers to the content-independent methods of teaching sustainability science and policy in the selected school programmes. Evidence was found of two pedagogical strategies, framing and problem solving.

Framing

Framing is a psychological concept that describes how different perspectives can be taken on a particular issue (Chong & Druckman, 2007) and how those perspectives can affect subsequent decision-making. Three practitioners discussed elements of framing within their program. Practitioners from Natural History Museum Aarhus and The Blue Planet emphasised the importance of not finger pointing. Instead, their approaches focus on promoting hope through empowering and inspirational stories. The practitioner of Odense Zoo discussed how the framing of *Threatened Animals* has changed, from previously being very negative, to now focusing on solutions and what students can do to make a positive difference.

Problem solving

Much of sustainability research focuses upon problem-solving (Gendron et al., 2017), and indeed, all the observed programmes contained elements of problem-solving within their exercises. They all followed a two-part structure, with brief presentations followed by exercises. Both *Inventions* and *Robot Programmer* included one generic and one sustainability exercise, while *The Sea Sweats and Plastic Fantastic* included two sustainability exercises.

The first exercise in *Inventions* asked students to search for an invention within a designated area of the museum and consider the problem that it solves. The following sustainability exercise built on this knowledge, and asked students in groups (using a set of materials) to design an invention that could help to solve a problem in relation to an SDG (i.e. Figure 6, a boat designed to remove plastic in the ocean using a net).

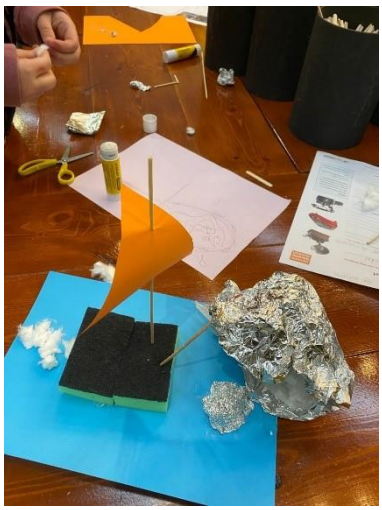

Figure 6. A group invention made at Danish Museum of Science & Technology.

In *Robot Programmer*, the first exercise led to students in groups programming their robots to travel back and forth between two designated lines, as quickly and precisely as possible. This turned into a competition, with a final taking place between the two closest groups (Figure 7).

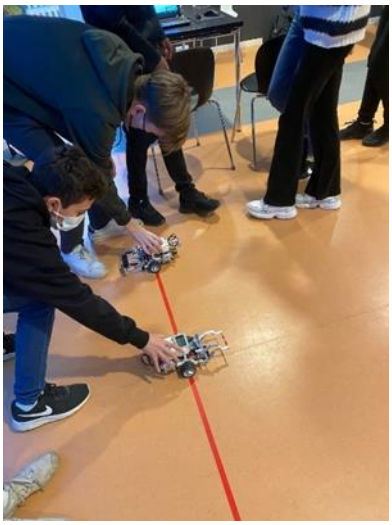

Figure 7. At Ecolarium, two groups compete in a final in programming a robot to travel to and from designated lines.

The second exercise asked students to programme their robots to collect plastic from the ocean. Finally, *The Sea Sweats and Plastic Fantastic* took the form of two scientific experiments centred on the 'wicked problems' (cf. Rittel & Webber, 1973) of climate change and plastic pollution. In groups, students measured the number of gill beats of a common goby and coral shark, and discussed their adaptations to a warming ocean. The secondary exercise involved students feeding food dye to brine shrimps and observing the take up through a microscope, simulating the ingestion of micro-plastics by marine animals.

Discussion

It was earlier discussed that the strong foundation of sustainability within Danish society may prompt a range (and depth) of sustainability education initiatives, shaped by the strengths and expertise of Denmark's OSSEIs. Accordingly, this study sets out to investigate the scope and status of sustainability education across Denmark. The results demonstrated a lack of sustainability programmes, however, those found contained a certain richness of sustainability topics across the five types of OSSEIs. Before these results are discussed and their implications for research and practice, the limitations of the study are briefly outlined.

Limitations

As a reminder, the OSSEIs of interest for this study were affiliated with the natural sciences and offering natural science education programmes. However, the researcher acknowledges how other disciplines, for instance art, play increasingly important roles in sustainability education (e.g. Crossick & Kaszynska, 2016; Heinrichs, 2018). Further, although botanical gardens make important contributions to out-of-school science education (e.g. Sellmann & Bogner, 2013), the desktop review did not find examples of these institutions offering sustainability programs. Finally, a lack of programme information on OSSEI websites occasionally hindered the desktop review, presenting a dilemma of whether content adhered to the criteria.

Relative Scarcity of Sustainability Programs

This study of the scope of sustainability education indicate that all five types of OSSEIs in Denmark offer sustainability education for visiting school classes. Even so, only about one fifth of the reviewed programmes contained sustainability content according to my criteria. Given the general focus on sustainability in Danish society, and the recent Decade of Education for Sustainable Development (2005-2014) (UNESCO, 2005); it would have been expected to find a far greater presence of sustainability in school programmes. Why is sustainability not more in focus?

One reason for the relative scarcity of sustainability programs could be the fuzziness and complexity of the notion of sustainability, which makes it difficult to operationalise for out-of-school education (Brown, 2019; Evans & Achiam, 2021). Another reason could be that the SDGs, which have become the de-facto conceptualization of sustainability in society (Sterling et al., 2017), do not always fit comfortably within the specific strengths and expertise of Danish OSSEIs. These results indicate that the type of institution strongly co-determines the sustainability content of the observed programme. This means, for instance, that for zoos and aquaria, designing sustainability programmes based on the SDGs is relatively straightforward, because SDG 14 (Life Below Water) and 15 (Life On Land) fit these institutional specialisations well. In fact, the most frequent topic for sustainability programmes in this study was biodiversity conservation, with zoos and aquaria offering over two-thirds of the sustainability programs. Furthermore, the recent sustainability strategy released by the World Association of Zoos and Aquaria (WAZA) focuses heavily on encouraging their member institutions to work with the SDGs (WAZA, 2020). However, interviews with zoo and aquaria practitioners discovered opposition to the explicit inclusion of SDGs into institutional practice. Many of their criticisms resonate with those expressed in academic circles (i.e. Liverman, 2018).

Aside from target 11.4, ‘strengthen efforts to protect and safeguard the world’s cultural and natural heritage’ (UN, 2015), there are no SDGs that have the same one-to-one correspondence with natural history museums,

science and technology museums or science centres. This probably means that these institutions must develop other focus points for sustainability education. One example is the interdisciplinary wicked problem of climate change (Cross & Congreve, 2020), which indeed was the only topic present across all five types of OSSEIs. As a counterpoint to this, museums, science centres and other OSSEIs are increasingly being tasked with educating the public for a sustainable future (e.g. Janes & Grattan, 2019; Janes & Sandell, 2019). Recent discussions in organizations such as the International Council of Museums or the Science Centre World Summit seem to reflect this ambition; however, quantitatively speaking, the researcher find themselves in agreement with Wals, (2010) who considers the level of democratic led action in sustainability education in Denmark to be insufficient to adapting to and mitigating the global sustainability challenges.

The Influence of Formal Education

The output of the status of sustainability education produced four themes, including that of formal education. Results from the thematic analysis indicate the influential role on OSSEI practice played by schools and the curriculum. The more reductionist school curriculum differs greatly to the systems-based approach taken by OSSEIs, with school subject boundaries running counter to the interdisciplinary and problem-based nature of sustainability. As shown from the interviews with teachers, they may struggle to conduct worthwhile pre and post activities because of these things. Research has shown how students' prior knowledge affects a visit to an OSSEI (i.e. Beiers & McRobbie, 1992). The teacher has an important role to play here in the form of mediating such a visit, particularly as OSSEI practitioners find it challenging to offer experiences fitting perfectly with students' prior knowledge (DeWitt & Storksdieck, 2008).

The close association of school curricula and OSSEI practice is perhaps hindering progress on sustainability education in programmes for visiting schools and contributing to the scarcity of sustainability education found in this study. Limiting themselves to the curriculum content perhaps makes it more difficult for OSSEIs to play to their areas of strength and expertise (see Evans & Achiam, 2021). Many OSSEIs maintain their own elements of scientific research, and so avoid the delay seen in formal education, caused by the need for research to be published and then added into curricula and corresponding material (Berg et al., 2021). A close association with the school curriculum potentially erodes away at this unique position. Finally, however, this is balanced with acknowledging the importance of OSSEIs in attracting visiting school classes, confirming their educational purpose in a rapidly changing society. Maintaining strong curriculum links within a programme may give greater meaning to a visit and can ensure the support of school leadership. Wolins, Jensen & Ulzheimer, (1992) found that curriculum links added to the long-term impact of school field trips to an OSSEI.

Pedagogy of Sustainability Education

Sustainability education aims to produce transformative learning experiences (Marouli, 2021) leading to a greater educated and motivated citizenry, by using pedagogical tools such as problem solving, critical thinking and decision-making (Thomas, 2018). Framing and problem solving were the main pedagogies found within the sustainability programmes. When framing programme content, the balance between disseminating a more positive outlook and human caused sustainability challenges can be very difficult to achieve (Esson & Moss, 2013). Programme observations provided a detailed insight into problem solving within sustainability education, with this method of learning a solution to preparing students for the challenges of sustainability. OSSEIs are well placed to provide problem-based learning, due to their close association with society and the complex, real-world issues we all face (Berg et al., 2021).

Conclusion

It is important to note the constraints that OSSEI program developers and educators are under in producing effective sustainability education, including funding, leadership, the level of expertise required, and the short time for an education session. In the light of the results of this study and in relation to prior research, it is essential that OSSEIs move away from a more reactive approach to sustainability policy (i.e. curriculum changes and specialised organization initiatives), to allow for a more proactive thinking mind-set within sustainability practice, using their unique areas of expertise. Taking into account the strong foundation of sustainability in Danish society, curriculum focus on sustainability and the SDGs, coupled with the urgent level of global action required, it is not overly ambitious to suggest that the majority of school programmes contain explicit, action-orientated sustainability content. With the global nature of sustainability challenges, the researcher hopes that scientists, policymakers and practitioners across Denmark and further afield view these findings to be of use moving forwards.

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We now move from Paper Two to Paper Three

9.3 Paper Three

Expressions of Agency in Out-of-School Sustainability Programmes: Moving Towards Guidelines for Sustainability Education

Evans & Achiam (manuscript)

Abstract

Sustainability education is an important means for societies to promote a transition to a more sustainable future. Younger generations are often discussed as the critical agents of change in terms of sustainability, and early adolescents often display positive attitudes towards science. Our study aims to describe good practice in out-of-school sustainability education. We do this by selecting strong candidates for effective sustainability education based on our previous work, carry out observations of the selected programmes, and finally apply the Blanchet-Cohen, (2008) six dimensions to identify expressions of sustainability agency. We confirm the existence of five out of six dimensions in Blanchet-Cohen, (2008), meaning that we find five corresponding themes in the data set. Furthermore, we inductively find a sixth theme; the Sustainable Development Goals. We synthesise our results into a set of guidelines for sustainability education in out-of-school settings. Finally, we discuss the implications of our findings for out-of-school sustainability practice.

Introduction

Sustainability education has been identified as an important means for societies to promote a transition to a more sustainable future (Filho et al., 2018; Marouli, 2021; Wamsler, 2020). The younger generations are often discussed as the critical agents of change in terms of sustainability (Bigger & Webb, 2010; Malone, 2013; UNESCO, 2014; Walker, 2017). Although they are influenced and sometimes hindered by factors such as social standing and parents (Blanchet-Cohen, 2008), the younger generations are able to explore ways to 'influence their own experiences and their world' (Blanchet-Cohen, 2010, p. 33). In this study, we focus on the importance of children and youth in the transition towards a sustainable future, and seek to understand how out-of-school science education promotes children's sustainability agency, that is, their ability to use their practical and contextual knowledge to alter the world towards their vision of sustainability (cf. Barton & Tan, 2010).

Even though sustainability agency plays a critical role in the green transition (Huttunen et al., 2021), it has been criticised for being unfocused (Geels, 2011; Huttunen et al., 2021; Lestar & Böhm, 2020; Pesch, 2015) or vaguely or implicitly defined (Fischer & Newig, 2016). This may be because agency in relation to sustainability is a relatively new notion, with no particular literature, community of researchers, or well-defined discipline (Teerikangas et al., 2021). However, based on research on sustainability science (e.g. Martens, 2006; Spangenberg, 2011) and sustainability education (e.g. Hume & Barry, 2015; Marouli, 2021), we might expect sustainability agency to be contextually defined, involve orientations towards action, have future directives, and act on both individual and collective levels.

In a study of 10-13 year olds attending a global environment conference in Canada, Blanchet-Cohen, (2008) identified six interconnected dimensions of environmental agency, all influenced by the individual and social context they were prompted by. In this framework, environmental agency progresses from a more basic sense of connectedness with the world, towards the building of confidence and belief in one's capacity to act. Here, we use these six dimensions as a lens to identify children's expressions of agency in selected sustainability education programmes, offered by out-of-school settings, or out-of-school science education institutions (OSSEIs), such as museums, science centres, zoos, aquaria, botanical gardens and planetariums.

Research has pointed to the important role of OSSEIs in the development of agency (e.g. Barton & Tan, 2010; Cameron, 2011), and in the provision of sustainability education (Evans & Achiam, 2021; Achiam, Dillon & Glackin, 2021). Accordingly, our study aims to describe good practice, that is, practice that promotes agency, in out-of-school sustainability education. We do this by selecting strong candidates for effective sustainability education based on our previous work, carefully interrogating the selected programmes, and apply the

Blanchet-Cohen, (2008) framework to identify expressions of sustainability agency. We finally synthesise our results into a set of guidelines for sustainability education in out-of-school settings, and discuss their implications for research and practice.

Method

In the following sections, we describe how we selected the programmes for observation, and how we analysed the data collected during the observations. It is worth noting here that we had initially selected on-site sustainability education programmes for 10-12-year-olds at five different OSSEIs located across Denmark. However, the COVID-19 pandemic challenged our data collection plan because of infections among staff, teachers and students, as well as visiting restrictions and temporary closures of institutions. We ended up being able to visit three of the original five institutions to observe their programmes.

Selection of Programmes

We selected education programmes based on our previous work. We selected programmes well aligned with the institutional characteristics (Evans & Achiam, 2021), that explicitly include sustainability content, and represent the diversity of OSSEIs (Evans, in press). We ended up with three programmes representing three different types of OSSEIs, namely a zoo, a science centre and a planetarium. All three programmes were new for 2021 (Table 1).

Table 1. An overview of the three on-site programmes selected for observation.

Institution	**Programme**	**Length**	**Target Grades**	**Theme(s)**
Copenhagen Zoo	Help The Chimpanzee	3.5 hours	Grade 4-6	Nature conservation, mathematics, genetics
Ecolarium	The World is Warming	1.5 hours	Grade 4-5	Climate change
Planetarium	Satellites and the Sustainable Development Goals	3.75 hours	Grade 5-7	Satellites, app development

In the autumn of 2021, the first author observed the programmes and collected qualitative data in the form of field notes, audio recordings, and informal conversations with educators, teachers and students. We made six observations in total: three at the zoo (two Grade 4 and one Grade 5), two at the science centre (both Grade 4) and one at the planetarium (Grade 6). It was not always possible to get permission to make audio recordings, thus these took place only for the three zoo observations.

Copenhagen Zoo, Help the Chimpanzee

The interdisciplinary programme *Help the Chimpanzee* was inspired by research from scientists employed at Copenhagen Zoo (see Frandsen et al., 2020) in the domains of nature conservation, mathematics and genetics. In the programme, students play the role of either a field biologist or scientist, with both professions working together to solve a task. Students spend time in various locations, including a zoo classroom, the chimpanzee enclosure and other areas of the zoo when using map coordinates to search for fake chimpanzee faeces.

We selected the programme because the zoo optimised their live collections to bring a sensory and experiential element to a programme focused on the real-world problems of illegal smuggling of young from central and West Africa, and deforestation of their rainforest habitats. The educator presents the conservation research carried out by the zoo, with DNA sequencing techniques identifying the sub-species of a chimpanzee, allowing for the return of illegally smuggled chimpanzees to their correct population. The programme replicates these techniques. Objects on display in the zoo classroom, such as a chimpanzee skull, were used by educators to bring a historical consciousness to their practice, and emphasised the thousands of years of history at Copenhagen Zoo.

Ecolarium, The World is Warming Up

The *World is Warming Up* is a climate change themed exhibition that forms the basis of the programme of the same name. In this programme, students are engaged in discussions about the causes of climate change, its various impacts such as the melting of ice caps, coral bleaching and forest fires, as well as action that can mitigate this global sustainability challenge (Økolariet, n.d.). The programme begins in a classroom with an educator-led presentation, followed by group activities and a general introduction to a worksheet corresponding to the exhibition's seven different thematic clusters. Finally, students explore the exhibition using the worksheet to navigate, answer questions, and solve problems.

We selected the programme because the science centre draws on its kinaesthetic, 'playful' conditions to operationalise, deconstruct and reconstruct the interdisciplinary topic of climate change from one that is complex and overwhelming, to one that allows students to 'feel' and experience climate change, and can be tackled at the individual level. The exhibition is full of interactive installations, including a layer of ice, a cow's head, a spinning wheel game, a body-heat sensor and virtual reality headsets.

Planetarium, Satellites and the Sustainable Development Goals

The programme *Satellites and the Sustainable Development Goals* is a collaboration between Planetarium and the UN City, with the latter providing the sustainability expertise. Starting in the Planetarium dome, students view a large projection of the night sky and the multitude of satellites found orbiting planet Earth, followed by group project activities in the Planetarium classroom. These activities involve the use of satellite data to develop a prototype of an app that addresses a sustainability problem, such as identifying clean sources of water for people in poverty.

We selected the programme because the planetarium uses its projection dome to immerse the students in the experience of gazing at the night sky, allowing the students to see the movement of satellites orbiting Earth. The planetarium dome further allows the students to virtually travel into space (cf. Achiam, Nicolaisen & Ibsen, 2019) to view satellite imagery of Mali in West Africa. Furthermore, in the Planetarium classroom, illustrations of planets, rockets and asteroids cover the walls.

Data Analysis

For the analysis, we pooled all the data (field notes, transcribed audio recordings, and notes from informal conversations with educators, teachers and students) to search for patterns across the data set. We used a mainly deductive or theory-driven approach based on Blanchet-Cohen, (2008) six elements of dimensions of environmental involvement: connectedness, engagement with the environment, questioning, belief in capacity, taking a stance and strategic action, but we also attempted to be sensitive to other emergent themes related to agency.

Results

We confirm the presence of five out of six dimensions from Blanchet-Cohen, (2008), meaning we found five corresponding themes in the data set. Furthermore, we inductively found an additional sixth theme crosscutting across all three programmes; the Sustainable Development Goals (SDGs). In the following, we describe the six themes and provide illustrations from the selected examples of OSSEI sustainability programmes in a zoo, museum and planetarium.

Theme One: Connectedness

Blanchet-Cohen, (2008) describes a sense of togetherness or connection with their natural surroundings as crucial for children to be able to act sustainably. In OSSEIs, traces of agency could be expressed as wonder, excitement or joy at their surroundings, either designed or natural. In all three programmes, we were able

to identify expressions of connectedness between the children and their surroundings, as described in the following.

At the zoo, a visit to the chimpanzee enclosure activated the senses (sight, smell and hearing), and instigated excitement among the students. We listened to the children's discussions on the similarities between humans and chimpanzees, with comments focusing on the physical appearance and behaviour of the species.

At the science centre, visiting the exhibition was clearly exciting for the students. The experiential nature of two virtual reality installations brought real-world sustainability challenges to life and allowed children to experience the impacts of climate change, i.e. a forest fire in the US and a coral bleaching event in Palau. Many students gathered around this particular exhibit to wait patiently for their turn, directing others in what to do, such as to 'look down' at the burning forest floor or degrading coral reef. Reactions to touching a cold ice block acted as a metaphor for the fragility of rapidly melting ice-sheets and glaciers.

At the planetarium, the dome brought a sense of wonder to the scale of space and the Earth's location in the solar system, and concretised the great distances between celestial objects. The moving objects in the night sky transfixed students and brought a cinematic feel to the programme.

Theme Two: Engagement with the environment

Blanchet-Cohen, (2008) describes how engagement allows children to achieve connections that are more concrete, and a deeper commitment through direct or indirect interaction with the environment. In OSSEIs, traces of agency could be expressed by children interacting with their surroundings, either designed or natural, and seeking information about what interests them. In all three programmes, we were able to identify expressions of children's engagement with their surroundings (the environment), as described in the following.

For the zoo programme, students played the role of either researchers in laboratory coats or field biologists in hiking hats. Throughout, students interacted with objects related to their profession, such as a motion sensor camera and a DNA scanner. These professions and their related objects helped to deepen students' engagement in the underlying storyline running through the programme; the importance of collaborating to solve real-world problems, aiding their developing identity with science, and being a scientist. Within the zoo classroom, one student was quiet and appeared to find difficulties in listening and focusing on the tasks. When visiting the chimpanzee enclosure, the first author observed the student proudly saying to a group member, 'Dr Isabella' and pretending to write it on the front of her folder. At all times while observing the chimpanzee enclosure, the student appeared transfixed by the animals, engaging fully in the activities and asking good questions. The students learn about the causes of the chimpanzee's decline, highlighted via a

comparison of population numbers between 1996 and 2016, for each of the four sub-species. This knowledge directly linked to the more emotional theme of *connectedness*, with children subsequently expressing empathy and worry. In addition, students had the opportunity to hold a local amphibian species called a beach toad, under threat in Denmark due to the draining of water-holes to create space for farming.

The science centre programme aided students in developing a deeper engagement with unsustainable practices associated with climate change, such as touching a furry cow's head to first connect with the cuteness of an animal, followed by an understanding of the global impacts of meat production, and potential dietary changes. An interactive spinning wheel highlighted 'realistic' possibilities for carbon reductions by Danish families, such as missing a holiday to Thailand for a bike tour in Denmark - the equivalent of saving 6,000 kg of carbon. Some students expressed sadness towards this particular suggestion, partly due to the fact they would prefer to travel somewhere new and exciting, but also that many of these choices were out of their control.

In the planetarium dome, students learnt about the number of satellites orbiting the planet, with now over 2,000 in use for objectives such as GPS, internet, developing climate models, taking photos, and measurements of temperature and ice loss. The development of app prototypes operationalised this knowledge to aid progress towards issues with food, education and water. At the end of the programme, the groups presented their prototypes to the rest of the class.

Theme Three: Critical questions

Blanchet-Cohen, (2008) describes how children can begin to find their own place and voice by being critical of sustainability issues, and the lack of solutions. In OSSEIs, traces of agency could be expressed by children expressing frustration with older generations, raising questions and condemning contradictions towards sustainability problems. In all three programmes, we observed children asking critical questions, prompted by the programme, as described in the following.

The zoo programme provided space for students to develop their own thoughts and opinions towards the unsustainable practices presented, by allowing time for questions, discussions and play. Children become aware of the dilemmas faced by people in Central and West Africa, in the basic requirement of providing for their families - leading to the illegal smuggling of young chimpanzees and deforestation of their habitats. For one student, this developed thoughts towards zoo practice in the keeping of wild animals in cages, subsequently asking if zoos kill animals that they exhibit. The zoo video explained that the planet does have enough water, clean air and healthy food for everyone (highlighted as the basic requirements for life) –

prompting questions from students on why these resources are not more fairly distributed to everyone, for example to certain communities in Central and West Africa.

The science centre programme developed an understanding for students of the 'wickedness' of sustainability challenges, such as a class discussion on population growth and the inequitable sharing of resources. One student stated to the class that 'humans are the worst things to have ever been on planet Earth', while others expressed frustration that they weren't involved in sustainable practices at home, such as monitoring if food was being thrown away, or the recycling of plastic. In response to questions on sustainability action, the educator tried to provide reassurances in the form of the Danish local election, which was to take place the following day on the 16th November 2021. The educator outlined that the Danish public usually place sustainability high on their agenda when deciding who to vote for, and that politicians listen to the public. In an informal discussion after the session, the educator placed emphasis on the parents:

> When they go home, we hope they will have discussions with their family and parents. We place a lot of emphasis on adults' responsibility. Children's parents are often their role models, and they want to be and do just like them.

Each group in the planetarium programme had a one-on-one discussion with the educator focused on their app prototype, the problem it aims to solve and interconnections with the SDGs (for example if their app is free to use, and so more inclusive - linking to SDG 10, Reduced Inequalities). This activity was far more personal and provided space for students to find their voice, and contextualise deeper engagement. Discussions aimed to outline how their app is using satellite data, for instance providing a social element for farmers using communication via messages and video to share advice, and measure rainfall.

Theme Four: Belief in your own ability

Blanchet-Cohen, (2008) describes how hope is a necessary part of children's belief that they can act sustainably. In OSSEIs, traces of agency could be expressed by children framing sustainability issues in an optimistic light, expressing confidence in their own ability to make a difference, and pointing to concrete and realistic solutions to the sustainability problems. In all three programmes, we observed children expressing belief in their own ability, prompted by the programme, as described in the following.

In the zoo programme, the educator emphasised the final section, 'What can we do?' as the most important part of the programme; a solutions orientated, positive framing of complex sustainability issues. The zoo video presented the SDGs as a global solution and a plan for the planet's future. Subsequently, the educator presented SDG 12, Responsible Consumption and Production and SDG 15, Life on Land as solutions to the unsustainable practices discussed, and children wrote down on a postcard two 'realistic' actions they could

undertake to help protect the world's animals. Examples of responses include ‘working hard at school’, ‘to recycle all paper and plastic’ and ‘to take care of all animals’. By student’s collaborating in their role of researcher or field biologist, they solve the problem by identifying the correct sub-species of the stolen baby chimpanzee, and are subsequently rewarded with a moment of joy of returning the animal home.

In the science centre programme, the educator highlighted ‘how lucky we are in Denmark in comparison to other countries, in terms of the amount of scientific and technological knowledge held, allowing Denmark to adapt and mitigate to climate change more effectively’. One of the exhibits, ‘The Climate Experiment’ discusses one sustainable behaviour carried out for each month of the year, such as reducing meat consumption in February and going on a climate friendly holiday in July, with the number of tons of CO2 saved per year outlined. With the engagement of their family, these attainable actions could provide hope for students and provide a belief they can act sustainably.

In the planetarium programme, the educator presented the SDGs in a similar way to the zoo programme, in that they provide hope for the future and are a sign of global cooperation – with 193 countries supporting them. In a question to students, ‘can we achieve the SDGs by 2030?’, many students answered no and appeared downcast. After the educator emphatically stated that she thought we could, many students appeared more hopeful, with some raising two hands in the air to express this.

Theme Five: Targeted action

Blanchet-Cohen, (2008) describes how children get involved in, or even take the initiative to act sustainably, when they’re able to place themselves in their own physical and social context (at home, in the classroom, on a shopping trip) in a conscious, informed and targeted way. In OSSEIs, children express agency when they formulate knowledge that is actionable in their particular context. In two of the programmes, we observed expressions of targeted action, as described in the following.

The zoo programme provided students with actionable knowledge via a class exercise involving the use of cards displaying the supply chain of paper from source (i.e. Central and West African rainforests) to consumers. The educator outlined the supply chain while handing out individual cards to students:

> You want a salary, and so you cut down trees in the rainforest. When you’ve done that, you sell them to the truck here, they drive them further to the factory, and then you sell them to the truck, which drives them further to the next factory to make paper. The paper is then driven from the factory to the shop. In the shop, you have visiting customers.

This exercise highlighted the power held by consumers in the choosing of sustainable products (i.e. certified by the Forest Stewardship Council, or FSC) over unsustainable alternatives, and the positive impacts that transcend back up the supply chain, by asking the students 'who decides on what shall happen?'. The common response is highlighted below.

> Students: 'us'!! <emphatically>
>
> Educator: Great, so there are some of you that have thought about it – and exactly it's you that can choose. It's you that has the power!

This activity prompted responses from students in relation to their own pro-environmental behaviour, often associated with parents, for instance one student stating 'as a family, we used to only buy non-organic food, but now we always buy organic'. One student noticed the FSC label on their zoo folder and exclaimed, 'I have FSC here!'. Another student discussed a recent trip with her parents to Bauhaus, a Danish retail chain:

> My mum always looks out for FSC products in Bauhaus. One time my Dad put some regular wood into the shopping trolley – it is bad for the environment! Therefore, my Mum took it out and went to see if any FSC wood was being sold. There was and so we bought that instead!

The science centre programme provided actionable knowledge through the use of circular cards highlighting behavioural choices, such as meat consumption, flying, driving a car, plastic straws, product and food choices - to instigate group discussions on sustainable behaviours. Much discussion focused on Christmas, most likely due to the observed programmes taking place in the months leading up to it . One student, in dialogue with the educator, mapped out the supply chain of meat, as well as the impact consumers can have in their choices.

> The supermarket is full of meat, so if we buy less meat, less would be supplied for consumers. Therefore, less animals would be needed and so more space for nature.

Theme Six: The Sustainable Development Goals

The sixth theme crosscuts the other five themes. In the majority of expressions of agency, the SDGs played a role in the underlying activity or storyline. The SDGs are recognisable; they effectively highlight for the children the interconnectedness i.e. synergies and trade-offs between different sustainability problems. All three institutions incorporated the SDGs into their selected programmes, using them in different ways and at different times, to concretise and operationalise the notion of sustainability.

In the zoo programme, the final part called 'What can we do?' began with a short video on the SDGs. Following the video, the educator used the goals to highlight the causes of the unsustainable practices of illegal smuggling of baby chimpanzees and deforestation of their habitats. Attributed goals include poverty, hunger and education (SDG 1, 2 and 4), and furthermore how these can in turn affect progress towards other sustainability issues such as clean water and sanitation (SDG 3) and gender equality (SDG 6). Next, the educator presents SDG 12 and 15 as important goals to help chimpanzees and their habitats.

In the science centre programme, the educator introduced the SDGs very early on within the classroom-based presentation, as a way to concretise the notion of sustainability into seventeen different workable problems. Additionally, the goals were presented in the following three segments; goals 1-6 focused on looking after humans, 13-15 on looking after nature and 16-17 to help everyone.

The planetarium programme used the SDGs as one of the central components. Students learnt about challenges facing the population of Mali in West Africa, in terms of food, education and water. Their app prototypes aimed to provide solutions in achieving the following SDGs: Goal 2, Zero Hunger, Goal 4, Quality Education and Goal 6, Clean Water and Sanitation. In an informal conversation after the programme, the UN City educator described the SDGs in the following:

> The SDGs are a tool to breakdown sustainability. They provide an understanding of connections between global problems, and why going to school is important for their own lives. The point is not to be able to relate specifically to the 17 colourful boxes, but instead understand the interactions between the different challenges.

Discussion

Museums, science centres, zoos, aquaria, botanical gardens and planetariums (i.e. OSSEIs) have been indicated as playing important roles in the sustainability transition (i.e. Hamilton & Christian Ronning, 2020; Hansson & Öhman, 2021; Zelenika et al., 2018). Our study supports this, in that we have observed the whole spectrum of agency – from a more basic sense of connectedness with the world towards the building of confidence and belief in one's capacity to act (Blanchet-Cohen, 2008) – across three different types of OSSEIs. Even so, previous research has shown that in general these institutions have difficulty in operationalising sustainability for their educational practice (Evans & Achiam, 2021). We hope that the guidelines can support this process, and the discussion will proceed in the following way. First, we outline the methodological limitations of the study, before proceeding to the guidelines and their implications for sustainability education practice.

Methodological Limitations

An important limitation of this study is that we attempt to identify expressions of sustainability agency in conversations in OSSEIs that may be 'fleeting and ephemeral' (Dillon, 2003, p. 222). This means that we may have missed important expressions of agency from the children. For instance, we were not able to identify Blanchet-Cohen, (2008) dimension of *taking a stance* in the data. On the other hand, Blanchet-Cohen, (2010) argues that students aged 10-12 years old have sufficient language skills to coherently express themselves. This lends support to our approach of listening to children's conversations as one way of observing sustainability agency.

Another potential limitation is the choice of the Blanchet-Cohen, (2008) framework as an analytical lens. This framework was developed to describe more long-term environmental involvement, which arguably is different from that of the short-term involvement a visit to an OSSEI might prompt in school classes. This might in some way explain our inability to identify the theme of *taking a stance* in our data as mentioned above. Even so, the fact that observed traces of sustainability agency related to five of the six dimensions from Blanchet-Cohen, (2008), reflects the utility of the framework.

Directives for Sustainability Education

The six guidelines are directives for sustainability education in out-of-school settings, to help early-adolescents develop agency in sustainability programmes. In the following, we contextualise the guidelines and discuss their implications for practice.

Guideline One

Allow/help children to connect with, notice, observe and immerse themselves in their physical surroundings, for instance via an animal enclosure, a kinaesthetic exhibition or a cinematic dome.

OSSEIs provide experiential, immersive experiences for visitors (Achiam, Nicolaisen & Ibsen, 2019; Clayton, 2017; Pedretti, 2004), leading to the development of personal connections with nature and the world around them. These connections can instigate emotions such as empathy, which acts as a powerful platform for societal concern and responses towards sustainability issues, such as climate change (Clayton, 2017; Clayton et al., 2014).

Guideline Two

Allow/give children time and opportunity to discover and interact with their surroundings, for instance by using objects, interacting with exhibits and developing products/ideas.

With research literature pointing to schools as inadequately engaging children in science (i.e. Sjøbeg & Schreiner, 2005), this learning could be complemented by visits to OSSEIs (Braund & Reiss, 2006). These sites incorporate both real and virtual worlds into their practice (Braund & Reiss, 2006), and hold unique conditions and scientific expertise (Evans & Achiam, 2021). Visits to OSSEIs can play an important role in children exploring their relationship with science, and a child's identity towards the life of a scientist (Heeg, 2022). We know from Achiam, Lindow & Simony, (2019) that children in out-of-school settings (i.e. a natural history museum) interact with scientific objects in ways that are context bound. A deeper engagement in sustainability lends itself to the importance of collaborative problem solving, for instance between a school and OSSEI (Insulander & Öhman, 2021).

Guideline Three

Allow/help children to (dare) ask their own critical questions, to discover the complexity of the problems and the conditions that hinder action towards sustainability challenges, for instance illegal deforestation, unequal distribution of resources and population growth.

Raising critical questions is an essential component of sustainability science (cf. Spangenberg, 2011), and it is thus not surprising that critical questioning is also considered an expression of sustainability agency (Smith & Watson, 2019). Even so, children may have difficulty in using questions to seek their place and voice in the world (Blanchet-Cohen, 2008) because they rarely have control of the decisions related to those questions due to their position in the family, their level of cognitive development, or simply economics (Heimlich, Searles & Atkins 2013). On the other hand, research has pointed out the efficacy of intergenerational learning in relation to climate action, possibly due to the robustness of children's beliefs in the face of adults' denials or their independence of political ideologies and worldviews (Lawson et al., 2018).

Guideline Four

Frame sustainability problems in a positive or constructive way that gives the children hope by pointing to concrete and realistic solutions to the sustainability problems, for instance highlighting global and local cooperation, collaborating and providing materials to take home.

The research literature points to the importance of providing hope in sustainability education (Bryant & Ellard, 2015; Evans, 2015; Ojala, 2017); a component of a transformational and inclusive approach to learning called the 'green pedagogy' (Weirsøe, 2021). For instance, illustrations of climate change that induce feelings of fear and paralysis can be counterproductive, doing more harm than good in the efforts of encouraging individual and collective action towards a sustainable future (O'Neill & Nicholson-Cole, 2009). A critical

element in influencing others to change their behaviour is the providing, supporting and reinforcing of specific, 'realistic' actions one can carry out (Heimlich, Searles & Atkins, 2013).

Guideline Five

Make sure that the teaching process helps the children to define and qualify their own approach to acting on sustainability issues, for instance via providing actionable knowledge and recreating supply chains.

The central motto of the sustainability movement, 'think global, act local', drives home the point that sustainability action, undertaken by individuals, is necessarily local and context-bound (Jasanoff, 2010). Sustainability agency thus entails a strong grasp of what opportunities are afforded by one's concrete context and position, and indeed, as previously mentioned, research shows that when OSSEIs provide and support opportunities for specific actions, their visitors are often successful in accomplishing them (Heimlich, Searles & Atkins, 2013). OSSEIs would thus do well to draw on their situatedness in their efforts to support sustainability agency (Janes & Sandell, 2019). Trott & Weinberg, (2020) analyse a long-term after-school programme on climate change (with additional off-site activities) for children 10-12 years old, with place-based, participatory, and action-focused pedagogies; finding positive changes towards science engagement and action.

Guideline Six

Use the Sustainable Development Goals actively, by showing concrete connections between the goals and children's everyday life.

Although having received much criticism (cf. Liverman, 2018), the SDGs present a future orientated approach to sustainability education, elevate the conversation to the global level and highlight to children the seriousness that the world's adults are now taking sustainability challenges. The seventeen goals have multiple synergies and trade-offs, which highlight the connections between different sustainability issues (Kroll, Warchold & Pradhan, 2019). By grasping how the different elements of sustainability issues impact on each other, one can not only achieve change on the individual, but also systemic level (Steiner et al., 2019). The goals directly make reference to the critical roles played by OSSEIs in moving towards a more sustainable future (cf. Petti et al., 2020).

Conclusion

These guidelines present a framework for sustainability education in out-of-school settings. The fuzziness and complexity of sustainability creates difficulties for these institutions in operationalising sustainability for their educational practice, and we hope that the guidelines can support this process.

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We now move from Paper Three to Paper Four

9.4 Paper Four

Museums Beyond Neutrality

Evans, Nicolaisen, Tougaard & Achiam, (2020)

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, and because realisations of the non-neutrality of the scientific endeavour have been much longer in the making in the natural sciences than in other disciplines. Even so, the arguments we make could be considered in other contexts and 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. Kathleen McLean 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 (McLean 1999, 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 sixteenth 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 often not questioned (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 or older adults (Garibay, 2011; Dawson, 2014; OECD 2018). We thus contend that not only is neutrality impossible, but also that feigning neutrality (by supporting the status quo) can seem excluding 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, New York and Oslo. 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 scientific rather than a political point of view (Anonymous, personal communication, 20/10/19).

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?

As researchers in the natural sciences, we do not claim to have in-depth expertise in the detailed workings of science 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

Even though not all science museums have collections (e.g. science centres), for many institutions they play an important role in research and visitor engagement. Although the historical 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 characterized 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 (science) museum professionals to consider the day-to-day and long-term implications of a museum beyond neutrality.

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End of thesis - thanks for reading

I did it!