Exploring Living Nature

Modes of observation in history, teaching and learning
A phenomenological approach

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University of Agder

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Summary

The purpose of this study is to phenomenologically explore the practices of observing living nature in history, teaching, and learning, and to discuss potentials and constraints with teaching and learning observational practices in primary school. The main research question is: *What is the nature and meaning of observing living nature in science education in primary school?* In my experience the study of biology requires careful observation, but research show that the process of observation is often underestimated in science teaching and learning or taken for granted or even ignored. In all sciences, observational practices are of fundamental importance but still, these practices seem to be a blind spot in school. In addition, research reports of an ongoing massive loss of species and nature, an ongoing loss of knowledge about nature, and a seemingly parallel ongoing loss of attention in terms of what several studies describe as a blindness to nature.

The research design of my PhD-project has three phases: *Phase 1* prepare four teaching cases from the history of science that demonstrate complementary modes of observing living nature, *Phase 2* implements the four cases in a course for teachers in primary school, and *Phase 3* explores how the teachers implement the cases in school. Phases two and three are both related to the same case study where the unit of inquiry is a case with five teachers and their students in fifth grade in primary school. In the case study, my investigations have a phenomenological approach with the purpose to examine the students and teachers' lived experiences with observing living nature. I have made classroom observations, collected notes and reflection logs, and conducted interviews with both teachers and students.

In Phase 1, my analysis leads to a typology of four modes of observation: Case I about Aristotle demonstrates a comparative mode of observation. Case II about Maria Sibylla Merian demonstrates a holistic and aesthetical mode of observation. Case III about Carl von Linné demonstrates an analytical and systemic mode of observation. Case IV about Alfred Russell Wallace and Charles Darwin demonstrates an explanatory and synthetical mode of observation. I further apply an analysis to design and prepare the cases for teaching, and I summarize the analysis in a general structure for designing teaching cases.

In phases two and three, my phenomenological analysis of the interviews with both teachers and students, suggests eight themes that describe essential aspects of their experiences with observing living nature. The themes specify, among other things, how observation has an ontological meaning by bringing out the *things* in the world of the students and teachers, the interplay between learning observational skills and other skills, how practicing observation might change the role of the teacher, and the complexity in describing and understanding scientific observational practices for both teachers and students. The results of the analysis show that the teachers and students have different perceptions of what matter in practicing observation of living nature that sometimes challenge each other. My findings suggest that teaching observational practices that invite the students to pay attention and respond to what living nature presents to them, may be an alternative to teaching as telling the students what to look for. The criteria for what matter in an observation are not given and what kind of skills the students practice may change their perception of what is relevant to observe. The question is not only what kind of knowledge the students get when practicing different modes of observation, but how both the 'things' in living nature and the students come into being through these practices.

Implications of my findings from all the three phases point to two issues that I explore further in the last part of this thesis: (i) *Ethical attention* in observational practices. In a model I suggest conditions for practicing an ethical attention in the triangle of teacher, student, and phenomena in living nature. In teaching, the model can support the teacher in considering what is valuable, good, or important, to pay attention to in nature, and how the students can be invited to explore those phenomena in nature in responsible ways. (ii) Conditions for more *sensible observational practices* in primary school. By sensible observational practices I mean observational practices that are contextualized within the students' familiar world, and that emphasize students' sensuous, embodied experiences and emotional involvement in these practices. I present two models as a basis to discuss the relationship between the students, the phenomena in living nature, and (scientific) representations in science teaching and learning. The first model show how (scientific) representations may become a wedge between the students and the phenomena in living nature under certain conditions, instead of bringing them together. The second model is a development of the first and illustrates observational practices as dynamic processes where the phenomena in living nature and the students are brought together, and where scientific representations may develop from the students' own experiences and induce an opening to new experiences.

Finally, I point towards a fifth teaching case which suggest a mode of observation that complements an anthropocentric perspective. Case V describes a *participatory and empathetic* mode of observation to investigate multiple meaning-making processes, a mode of observation that invites the students to identify themselves with other living beings in a very concrete and fundamental way.

Sammendrag

Hensikten med denne studien er å undersøke hvordan lærere og elever i barneskolen kan utforske den levende delen av naturen gjennom ulike observasjonspraksiser som bygger på fire vitenskapshistoriske caser. Videre er hensikten å drøfte muligheter og begrensninger for å øve observasjonsferdigheter i naturfagundervisningen i barneskolen. Det overordnede forskningsspørsmålet er todelt: *Hva kjennetegner observasjonspraksisene knyttet til levende natur i undervisning og læring av naturfag i barneskolen, og hvilken betydning har disse praksisene for lærere og elever?* Observasjon er av grunnleggende betydning i alle naturvitenskaper, likevel viser forskning at observasjonsprosessene ofte blir undervurdert, tatt for gitt, eller til og med ignorert i undervisning og læring av naturfag. Samtidig rapporterer forskning om et pågående massivt tap av arter og natur, et pågående tap av kunnskap om naturen, og en pågående manglende oppmerksomhet mot mangfoldet naturen i form av en naturblindhet.

Forskningsdesignet til ph.d.-prosjektet mitt har tre faser: *Fase 1* forbereder fire undervisningscase fra vitenskapshistorien som viser komplementære måter å observere levende natur på, *Fase 2* implementerer de fire undervisningscasene i et kurs for lærere i grunnskolen, og *Fase 3* utforsker hvordan lærerne implementerer de samme fire undervisningscasene i skolen. Fase 2 og 3 er videre begge knyttet til en *casestudie* der undersøkelsesenheten er fem lærere og deres elever i femte klasse i grunnskolen. I casestudien bruker jeg en fenomenologisk tilnærming for å undersøke elevenes og lærernes erfaringer med å utforske den levende delen av naturen gjennom ulike observasjonspraksiser. For å få tilgang til elevenes og lærernes erfaringer har jeg gjort klasseromsobservasjoner, samlet inn notater og refleksjonslogger, og gjennomført intervjuer med både lærere og elever.

I første fase leder analysen min til en typologi av fire observasjonsmåter: Case I om Aristoteles demonstrerer en komparativ observasjonsmåte. Case II om Maria Sibylla Merian demonstrerer en helhetlig og estetisk observasjonsmåte. Case III om Carl von Linné demonstrerer en analytisk og systematisk observasjonsmåte. Case IV om Alfred Russell Wallace og Charles Darwin demonstrerer en syntetiserende observasjonsmåte som har til hensikt å forklare. Videre gjøre jeg en didaktisk analyse av de fire casene for å designe og forberede dem til

undervisning, og oppsummerer analysen i en generell struktur for utforming av lignende undervisningscase.

I andre og tredje fase fører den fenomenologiske analysen av intervjuene med lærere og elever til åtte temaer som beskriver vesentlige aspekter ved både lærernes og elevenes erfaringer med det å observere levende natur. Temaene beskriver blant annet hvordan observasjon har en ontologisk betydning ved at det som finnes i den levende naturen blir til for elever og lærere i prosessen, de viser samspillet mellom å lære observasjonsferdigheter og andre ferdigheter, hvordan lærerrollen kan endres i observasjonspraksiser, og kompleksiteten i det å beskrive og forstå vitenskapelige observasjonspraksiser for både lærere og elever. Resultatene av analysen viser at lærere og elever kan ha ulike oppfatninger av hva som er viktig i en observasjon av levende natur og at disse oppfatningene noen ganger utfordrer hverandre. Mine funn tyder på at observasjonspraksiser som inviterer elevene til å være oppmerksomme mot og i dialog med fenomenene i den levende naturen, kan være et alternativ til en undervisning som forteller elevene hva de skal se etter. Kriteriene for hva som betyr noe i en observasjon er ikke gitt og hva slags ferdigheter elevene øver på kan endre deres oppfatning av hva som er relevant å observere. Spørsmålet er ikke bare hva slags kunnskap elevene får når de praktiserer ulike observasjonsmåter, men hvordan både *tingene* i den levende naturen og elevene blir til gjennom disse praksisene.

Implikasjoner fra funnene i alle de tre fasene peker på to problemstillinger som jeg utforsker videre i den siste delen av denne avhandlingen: (i) *Etisk oppmerksomhet* i observasjonspraksis. I en modell som viser trepartforholdet mellom lærer, elev og fenomenene i levende natur foreslår jeg betingelser for å praktisere en etisk oppmerksomhet. Modellen kan støtte lærere i å vurdere hva som er verdifullt, bra eller viktig å rette oppmerksomheten mot i naturen, og hvordan elevene kan inviteres til å utforske disse fenomenene i naturen på ansvarlige måter. (ii) Betingelser for mer *meningsfulle observasjonspraksiser* i grunnskolen. Med meningsfulle observasjonspraksis mener jeg observasjonspraksiser som er kontekstualisert innenfor studentenes kjente verden, og som også legger vekt på elevenes sanselige, kroppsliggjorte opplevelser og emosjonelle involvering i disse praksisene. Jeg presenterer to modeller som grunnlag for å diskutere forholdet mellom elevene, fenomenene i levende natur, og (vitenskapelige) representasjoner i undervisning og læring av naturfag. Den første modellen viser hvordan (vitenskapelige) representasjoner i noen tilfeller kan bli en kile mellom elevene og fenomenene i den levende naturen, i stedet for å bringe dem sammen. Den andre modellen er en utvikling av den første og illustrerer observasjonspraksiser som en dynamisk prosess. En prosess hvor fenomenene i den levende naturen og elevene bringes sammen en bevegelse, og vitenskapelige representasjoner utvikler seg fra elevenes egne erfaringer og åpner for nye erfaringer i neste bevegelse.

Til slutt peker jeg på et femte undervisningscase som foreslår en observasjonsmåte som komplementerer det antroposentriske perspektivet i de fire foregående casene. Case V beskriver en deltakende og empatisk observasjonsmåte for å undersøke meningsskapende prosesser, det er en observasjonsmåte som inviterer elevene til å identifisere seg med andre levende organismer på en konkret og grunnleggende måte.

Contents

List of tables and figures

PART I: Introduction and background

In this thesis, I will investigate the phenomenon of observing living nature in the context of teaching and learning science in primary school. To me, there are at least three points of entry into this investigation. The first is my own history of experiences as a child, student, biologist, teacher, and teacher educator; experiences that have led to a deep interest in and abiding questions about how to observe and recognize the diversity of living nature. The second is research in science education that demonstrates friction between observational practices, scientific knowledge, and our experiences in the world. The third point of entry is phenomenology as an attitude and approach to investigating observation of living nature; both as a philosophy to understand the foundation of knowledge and knowing, and as an approach to practice both education and research. I will elaborate on these three entry points in Part I and II and thereby give a background for my thesis.

My aim in Part I is to introduce topics and give a background for questions regarding the phenomenon of observing living nature in education, by describing my own lived experience in Chapter 1, and then giving an overview of the research context in Chapter 2. In Chapter 3, I will define and delineate central concepts, describe the purpose of the study and the research questions, and give an overview of the structure of the whole thesis.

1 My lived experience

> To be playful and serious at the same time is possible, and it defines the ideal mental condition. (Dewey, 1910).

1.1 Being a child

It is hard to remember how the world looked like when I was child. And as a biologist, it is hard to recall how I perceived plants and animals in nature before I gained the knowledge and experience which has now become a part of me. However, I do remember one early experience that tells me something about how I experienced nature as a child:

I can't remember exactly where I was, but the landscape was a woodland edge. It was summer and I guess that I was around four or five years old. While walking about, I discovered what I perceived as a forest of miniature spruce trees. The puzzle was that although the "trees" looked like tiny spruces, they seemed to be fully grown, and I realized they were not spruce of seedlings. They were so delicate, but still completed in their form. I remember it like an opening into a magical miniature world within the larger forest, and I could easily imagine other miniature beings living there among the miniature trees. I can't remember telling anyone, and it may all have happened briefly, but the experience stayed with me. I can still recall the wonderous sensation of the possibility of this miniature world existing within the larger world.

1.2 Being a biology student

It was probably not until I studied biology in high school that I understood that what I had discovered as a child was a woodland horsetail *(Equisetum sylvaticum*). For me as a biology student, learning the name of the peculiar horse-tail plant, somehow took away the sense of magic of that miniature world, but in another way, it opened a whole new sense of wonder about all the different life forms that exist. After high school, I decided to study biology at the University of Oslo, and I gradually specialized in ecology and botany and took a master in botanical ecology. Throughout my biology education, the fascination with the diversity of life, went hand in hand with the struggle and frustration to get a grip on how to recognize all the different plants and animal species in nature. As part of the education, we went on fieldtrips to different localities such as woodlands, meadows, mountains and even abroad to the Mediterranean. I remember asking the professors on several occasions, “How do you recognize this plant species, or how do you distinguish this one from that one?”. Their answers were often something like: “I just do”, or they said something about the plant’s leaves or petals literally in Latin. It was not that the professors could not point to specific traits to look for in order to distinguish between two specific plant species; like for instance whether there are two small rows of hair on each side of the stem or not, which separate the Germander speedwell (*Veronica chamaedrys)* from the other species in the genus *Veronica*. The problem was rather that as a novice it is challenging, in the first place, to know how to distinguish one plant with a little blue flower from all the other plants with small blue flowers. The diversity of species is overwhelming once you start to get an eye for it.

Probably the most important thing I learned while being a biology student was that I had to train my ability to recognize species by observing plants over and over again, and I would ideally repeat for myself what plants I recognized wherever I went for a walk outdoors. I started to look at nature in a different way. I started to notice things like different grasses and mosses that I had not noticed before. Gradually, I also started to recognize the familiarity between groups of flowering plants, and after a while, I was able to organize (in a glance) many of the plants I saw in nature into different plant-families, which made the complexity a little less. After two summers of fieldwork as a master student, studying the ecological role of plant-diversity in a cultural grazing landscape, some of the plants became even more familiar to me. In some instances, I could recognize plant species by their seedling, or rosette of leaves on the ground, and I gradually got familiar with the structure and growth form of the different plant species in the meadow. In addition, studying the plants in the meadow by observing how they grew, their time of flowering, and how they interacted with each other (among other things), gave me an insight into the world of plants. The plants became present to me as significant living entities in a new way. Results from the studies were presented as tables and figures in my MSc thesis but did not seem to fully convey this insight. The scientific tables and figures demonstrated aspects of the world of plants that could be measured or counted in one way or another, but concealed aesthetical aspects like colors, smells, sounds and the sense of the plants' living presence.

1.3 Being a teacher and a teacher educator

When I later became a science teacher in high school, I realized that I lacked the tools to teach the students how to observe and recognize plants and animals in nature, other than telling them the name of the species. In my experience, like most people, I have a general tendency to forget the paths I myself have walked on to gain knowledge and after a while I simply take the knowledge I am left with for granted. To describe exactly how I for instance recognize a certain species is difficult, because by repeated experience I just do.

I also noticed as a teacher that, in general, the student's knowledge of local plants and animals was almost at zero, especially when it came to plants. However, to observe and recognize plants and animals in nature is not the focus of attention in the general science curricula in high school. As a result, I was preoccupied by other topics as a science teacher, and my own engagement with teaching the skills of recognizing plants and animals was lying fallow for some years. Only when I became a teacher educator at the university, after nearly 12 years of teaching science and mathematics in high school, did I return to the issues of teaching and learning how to recognize plants and animals in nature.

In the teacher education program, students need to build a foundation of knowledge and skills to be able to teach about how to recognize plants and animals, themselves. For teacher students, biology makes up around one third of an optional one-year science course in their education, and knowledge of species only makes up a small part of some of the topics in biology, like classification, evolution, and ecology. Due to this, the time and occasions for the students to observe plants and animals in nature to train their ability to recognize them, are very limited. As a teacher educator in biology, I started to ask myself: How can I give the students a foundation to build their knowledge and skills on, rather than simply telling them what they see? The image I had in mind was a student placed in the middle of a meadow to study the plants and animals there. What are the best questions for him or her to ask? How can he or she proceed when starting from scratch? These questions led me to wonder about how the first naturalists started their investigations of the overwhelming diversity of life when they had nothing to build on. What questions did these pioneers ask? How did they proceed? How did they go about observing, describing, systemizing, and explaining all the plants and animals that make up the living nature?

This is where the present project started. I studied the history of science to find important works and practices that led to new insights in the investigations of living nature. Gradually, I singled out four historical cases, representing five historical persons, that I thought demonstrated complementary modes of observation in the investigations of living nature. The idea was to use these cases in education to help the students practice observation of plants and animals by demonstrating essential questions and methods, and thereby hopefully opening nature's diversity for further explorations to the students.

1.4 Sensing the wonders of nature

In my experience, nature seems to invite a sense of wonder and almost infinite discoveries when students are given a chance to notice and recognize different plants and animals. Sir David Attenborough has been a host for a vast number of nature documentaries around the world through nearly seven decades. He has experienced many of the most spectacular natural landscapes and life forms on earth. In an interview with Prince William at the *World Economic Forum* in 2019, then 93 years old, Attenborough emphasizes an experience with a four or five-year-old boy noticing a common slug on his path:

> And he [the boy] said: *Look a slug! What a treasure!* And of course, he is right. I mean what are those two things it has in the front? What are they for? How does it move? What does it feed on? Astonishment! And that goes on and on and on. If you lose that first wonder. You have lost one of the greatest sources of delight and pleasure and beauty in the whole universe. […] So, caring for that brings joy and enlightenment which is irreplaceable.[1]

[1] World Economic Forum 22.01.2019. The Duke of Cambridge interviews Sir David Attenborough. Attenborough answers to a question about whether he is surprised that his documentaries still are so popular, to hear the full answer play from 1:43 -3:14: https://fb.watch/aBnN50oOfB/

I think Attenborough wants to express that the ‘treasures’ of living nature are everywhere and that children also intuitively experience them as such, even a common slug. He also underscores the life-long value of such discoveries.

Sadly, as both a student, teacher, and teacher educator, I have experienced that students, while being at school, seldom are encouraged to discover such ‘treasures’ in nature by paying attention and wondering about what they observe. Instead, the time and occasions for exploring living nature are limited. In many cases, the teachers themselves seem to lack the ability to recognize local plants and animals (which may have many reasons), and they may not have discovered the diversity, varieties, dynamics and nuances of plants and animals. As a result, there are probably many missed opportunities for the students to make important and wonderous discoveries in nature. In addition, many of the ‘natural’ areas in and near urban areas, like roadsides and small forests, have been greatly diminished by different kinds of development in the last couple of decades. Due to this lack of opportunities, time, skill, and knowledge, I will argue that the ability to observe and recognize local plants and animals has become a blind spot in school, because what the teachers do not recognize themselves probably does not exist as something significant to them. Being able to observe and recognize plants and animals in nature seems to be underestimated as a skill in school. Yet, it is one of the most basic skills in biology, and a foundational element in both classification, ecology, and evolution.

Rachel Carson, another renowned biologist, wrote the book *The sense of wonder* (Carson, 2017) towards the end of her life about experiences of making discoveries in nature together with her nephew. In one section of the book, she writes about how she observes the lichens in the woods when they are out on a walk on a rainy day:

> Having always loved the lichens because they have a quality of fairyland – silver rings on a stone, odd little forms like bones or horns or the shell of a sea creature (…). The woods path was carpeted with the so-called reindeer moss, in reality a lichen. Like an old-fashioned hall runner, it made a narrow strip of silvery gray through the green of the woods, here and there spreading out to cover a larger area (p. 38).

Carson's observation resonates with my own childhood experience with the horsetail. In this quote and throughout her book Carson demonstrates an attitude of being playful and serious at the same time. After many years of learning and teaching biology myself, I think this attitude, together with the appreciation of paying attention to plants and animals in nature, sums up what I find most important in the education and exploration of biodiversity. To me it means opening a door into the complexity and diversity of plants and animals, and inviting the students to pay attention, recognize, and explore, both playfully and seriously. In the deepest sense, it means to make the entities of living nature present and bring them into existence for the students.

2 Scientific knowledge, observational practices and knowing the world

> Philosophers and natural scientists started to listen to the voice of nature through very thick walls as it were, walls which let through only the thin and abstract sound of numbers and formulas. (Dahlin, 2001, p. 454)

> To be objective is to aspire to knowledge that bears no trace of the knower – knowledge unmarked by prejudice or skill, fantasy, or judgement, wishing or striving. Objectivity is blind-sight, seeing without inference, interpretation or intelligence. (Daston & Galison, 2010, p. 17)

2.1 Conceptual understanding and/or sense experience in science education

In science education there seems to be a trend of exclusive focus on conceptual cognition and concept formation, with a neglect of sense experience (Dahlin, 2001). It is a trend that follows from the created dualism in science since Descartes[2], between subject and object, and between nature and experience. This dualism is critiqued by Dewey among others and according to him it results in 'the spectator theory of knowledge', where "learning is best accomplished when the student is detachedly and objectively watching and listening, with the other senses, the body, and the feelings, as little involved as possible" (Dahlin, 2001, p. 456). Although constructivism, which emphasizes the students' active knowledge construction, is the prominent educational theory of knowledge today, the mind-body dualism seems to be persistent. Constructivism focuses on conceptual cognition, reducing the manifolds forms of experience in learning. Even the concept of deep-learning seem to be understood mainly as cognition, at least in the Norwegian curriculum for primary and secondary school, with a neglect of bodily experiences as learning (Dahl & Østern, 2019).

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[2] This dualism is called the 'mind-body dualism' or the cartesian dualism after René Descartes. In his famous work *Meditations on First Philosophy* from 1641, Descartes argues that the nature of the mind is completely different from that of the body, and therefore it is possible for one to exist without the other. From The Internet Encyclopedia of Philosophy: https://iep.utm.edu/rene-descartes-mind-body-distinction-dualism/

In science, constructed concepts, theories and mathematical principles often based on idealized situations are furthermore seen as explanations of observed phenomena, and tend to be taken as more real than the concrete phenomena they refer to. Harvey (1989) calls this 'the ontological reversal', a position where: "abstract models for a supposedly hidden reality behind concretely experienced phenomena take on a higher ontological status than these experiences themselves" (Dahlin, 2001, p. 458; 2003). In science education, the ontological reversal may lead to students feeling an alienation from nature and the loss of a fundamental sense of rooting in the world, because what the students learn in science class is conveyed as more real than their everyday lived experience (Pulkki et al., 2017; Roth, 2015; Østergaard, 2015).

In *Phenomenology of perception,* Merleau-Ponty reminds us that science is the 'the second order expression' of the experience of the world:

> Everything that I know about the world, even through science, I know from a perspective that is my own or from an experience of the world without which scientific symbols would be meaningless. The entire universe of science is constructed upon the lived world, and if we wish to think science rigorously, to appreciate precisely its sense and its scope, we must first awaken that experience of the world of which science is the second order expression. (Merleau-Ponty, 2012, p. Ixxii)

According to Merleau-Ponty here, the experience of the world is primordial to a scientific expression of the world. The basic ground in Merleau-Ponty's phenomenology is embodied lived experience which integrates subject and object into a non-dualistic structure where the body is intertwined with the world (Pulkki et al., 2017). This corresponds with Dewey's description of an experience as "a transformation of interaction into participation and communication" that integrates person and environment (Dewey, 2005, p. 22). And according to Dahlin (2003), to promote an *aesthetic* experience means to cultivate "a careful and exact attention to all the qualities inherent in sense experience"(p. 454).

How children experience with their bodies, explore and create meaning out of encounters in the natural world (without scientific concepts), driven by an intuitive sense of wonder, is demonstrated in an ethnographic study of two nature-kindergarten groups in Norway (Jørgensen, 2016). The children’s sense of wonder is related to their sensory experiences and emotional involvement with living organisms like jellyfish and beetles. Jørgensen (2016) describes how the children interact with the living organisms in a way that is both “play and reality” (p. 1148), initiating investigations themselves:

> Driven by curiosity and reflecting a playfulness in their actions, the children explored and created, which is what Dewey saw as important in helping the children to create meaning and gain new knowledge. The adults contributed to this in two ways. They were always available for questions and they gave the children time to explore (…). (p. 1150)

To engage and awaken the children’s experience of the world the most important part in this case was to facilitate for the children’s encounters with living nature and then give them time to explore. This corresponds with what Östergaard (2015) describes as two conditions (and challenges) for rooting in science education: “restoring the value of aesthetic experience”, and “allowing time for open inquiry” (p. 522). The act of being attentive may be described as directing itself both outwards and inwards at the same time (Östergaard, 2015). To understand lived experience as the body’s intertwining with the world means that being attentive towards living nature is the same as experiencing oneself with and within nature. This is in line with Biesta (2022a): “the whole point of education is to bring something into the student’s ‘field’ of perception” and “seek to awaken the students for the world and, through this, awaken them for themselves” (p. 222). Teaching is seen as a gesture that points towards something good, important, or worthwhile to pay attention to, but leaving it up to the students to figure out what to do with it. Such a gesture invites students to engage and participate in the world with and as themselves (Biesta, 2022a).

In science education the question is how to bring together the students’ experience of the world and scientific knowledge as an expression of the world (cf. Merleau-Ponty). Scientific knowledge is normally seen as representations of the world through concepts and theories. However, rather than a thing or a result or a representation (as in cognitive concept formation), knowledge may be seen as a process or practice of knowing the world (e.g. Dahl, 2019). In science education, to see knowledge as a practice of knowing the world, rather than a result or a representation, would mean a shift from emphasizing conceptual cognition and concept formation, towards learning as (bodily) experiences and something you do. Phenomena come into being through engaging in the world.

A phenomenon-based science education is an alternative to constructivism and cognitivism (Østergaard et al., 2008). An education that grounds itself in students' familiarity with the world and expands this familiarity through experiences that unite the everyday world and science, may counter the students feeling of alienation, and instead, foster a feeling of rooting (Roth, 2015; Østergaard, 2017). In a phenomenon-based science education, it is essential to promote and train sense-experiences, and then to bridge the gap between sense experience and concepts (Østergaard, 2015; Østergaard et al., 2007).

The German pedagogue and science (physics) educator Martin Wagenschein is central in this tradition. Wagenschein (2015) emphasizes that science, although enlightening, is a limited image and a particular aspect of reality. In school, the students need to start with the phenomena to experience how "natural science is possible and can become possible" (p. 157), and he elaborates:

> For abstract concepts that have not come into reality from their origin in the phenomena ("genetic") are misunderstood: Not as something that are constructed by us, but as something that exist; both in material, but also as magical realities, which are believed to lie behind everything as final causes and causes of the phenomena: the ontological misunderstanding of physics (p. 157; my translation from Danish).

Thus, without opportunities to engage in a process of knowing the phenomena in the world, it seems that neither the process of abstraction is possible for students. Wagenschein (2015) further describes the possibility of a double opening, where observing certain phenomena over time like for instance a pendulum, "opens the case so that it speaks, and it opens the students so that they engage" (p. 161; my translation). To prepare teaching, a science teacher must keep in mind the phenomena in nature, but also have an eye for the students experiencing them (Østergaard, 2011). Wagenschein describes three didactical principles that constitute a unity: the *genetic-socratic-exemplary* (p. 96). The genetic refers to *genesis*[3] of knowledge in the students, as coming into being of knowledge, and as

[3] From Latin genesis "generation, nativity, from Greek genesis "origin, creation, generation," from gignesthai "to be born," related to genos "race, birth, descent" (from PIE root *gene- "give

the child coming into being with the knowledge. For the teacher it means to prepare teaching which let the students discover knowledge and theories, instead of simply presenting them to the students. To make this *genesis* of knowledge possible, the teacher must apply the *socratic principle* of dialogue, and the *exemplary principle* to select topics to dwell on (p. 99).

Another German pedagogue Wolfgang Klafki builds on Wagenschein's principles and introduces the concept of categorical *Bildung*. In the German and Scandinavian tradition, *Bildung* is not understood as something that can be taught, it "is more of a concept of achieving capacity and skills than a set of facts and theories to be learned", and "a process of activating potential more than a process of learning" (Sjöström & Eilks, 2020, p. 56). The Scandinavian folk-*Bildung*, and the idea of an education for all, is related to Dewey's democratic education to promote democratic habits. Such an education emphasizes development of competences of the learner over learning of content knowledge (formal *Bildung*). In other traditions learning the content knowledge is prioritized over developing more general competencies (material *Bildung).* According to Sjöström and Eilks (2020), Klafki connect these views in his categorical *Bildung* and suggests that learning "should contribute to both material and formal gains in the learner" (p. 59).

To let the students engage and participate in a practice of observing living nature may be a way for the teacher to promote and train sense experience, as in a phenomenon-based science education. It may also be a way to create an opportunity for "a double opening" (cf. Wagenschein) and connect formal and material *Bildung* in the students (cf. Klafki). Further, to promote science education as a practice of being attentive may be crucial in a world where there seems to be an ongoing deafening and blinding process towards living nature, and where there is extinction of both species and experience.

2.2 Plant blindness

Several studies report a widespread condition referred to as *plant blindness*, where an individual fails to notice plants. (e.g. Allen, 2003; Balas & Momsen,

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birth, beget"). From Online Etymology Dictionary: https://www.etymonline.com/search?q=genesis&ref=searchbar_searchhint

2014; Jose et al., 2019; Krosnick et al., 2018; Schussler & Olzak, 2008; Thomas et al., 2022; Wandersee & Schussler, 1999). Wandersee and Schussler (1999) introduced the concept of plant blindness as a term that "emphasizes the perceptual and visual-cognition bases of why plants are often overlooked and neglected" (p. 84). They describe five characteristics of human perception that might explain the deficiency: 1) objects need to acquire meaning to be observed (inattentional blindness), 2) if objects are not sufficiently different from their background, they blend in with their surroundings, 3) plants grow in close proximity to each other and appear relatively stationary, which is a visual cue to group objects (individual plants and different plant species tend to be de-emphasized, with the totality categorized as 'plants'), 4) plants are generally non-threatening and can be ignored without dire consequences, and 5) plants offer fewer differentiators for humans to observe than animals, and the brain is basically a differentiator-detector (Wandersee & Schussler, 1999). Balas and Momsen (2014) demonstrate in an experimental study that plants are not detected as robustly as animals, nor do they capture attention resources as quickly. In addition, a number of studies find that many students do not even perceive plant as living organisms (e.g. Amprazis et al., 2021). The condition of plant blindness indicates that plants, in large, fail to become present to most people, and that they thus don't exist as separate and significant entities.

As an attempt to counteract plant blindness, Krosnick et al. (2018) designed and implemented the *Pet Plant Project* in an introductory course in botany including 209 students at Tennessee Tech University. The project was designed to provide an opportunity for the students to observe and interact with plants on multiple levels. Together with complementary lectures, the students grew and monitored an unknown plant from seed to maturity over the course of the semester. The project successfully decreased plant blindness among the students, and one of the results was that 73 % of the students noticed plants more after the project. This study is part of a growing body of research literature demonstrating that different educational activities may counteract plant blindness and make flora more interesting to people (e.g. Lindemann-Matthies, 2002; Nyberg & Sanders, 2014). These studies show that plant blindness is not simply a perception issue, but, as demonstrated by Krosnick et al. (2018), the opportunity to observe and interact with plants makes a difference in terms of how you perceive plants.

Although these studies indicates that plants in particular ends up in a blind zone due to our lack of attention and inability to detect them, the issue of not recognizing living nature is more pervasive than plant blindness and seems to include most groups of none-vertebrate organisms (Knapp, 2019). Related to the condition of plant blindness, are the concepts of *shifting baseline syndrome* (e.g. Hanazaki et al., 2013) or *environmental generational amnesia* (Kahn & Thea, 2017). The concepts describe how children of each generation perceive the environment into which they are born as normal, even though nature has become increasingly diminished and degraded over the last generations. Thus, there is a shifting baseline for what counts as healthy nature, but also of the perception of what exists in living nature. I will use the Norwegian author Ingvar Ambjørnsen to exemplify a "generational amnesia", and what we might call *bird-blindness*. In an interview with the magazine *Harvest,* he says:

> People don't notice the birds. This is something I find despairing when it comes to protecting species. Extinction of species becomes something completely abstract for some people, because in their world these species have never existed. They have never seen them. They have not even heard of them. (Ekelund, 2020; my translation from Norwegian)

2.3 Extinction of species - and of experience?

A massive global loss of biodiversity is reported in several recent studies (e.g. Ceballos et al., 2017; Ceballos et al., 2020; Gilbert, 2016; Hallmann et al., 2017; IPBS, 2019). This development threatens all the sustainable development goals defined by the UN[4]. At the same time, there seems to be an ongoing loss of knowledge about biodiversity among students (e.g. Ballouard et al., 2011; Buck et al., 2019; Lindemann-Matthies et al., 2011; Miller, 2005; Yli-Panula & Matikainen, 2014). In the article *Just a small bunch of flowers,* Buck et al. (2019) presents a study on the effects of introductory courses in plant identification at German universities, including more than 500 students in total. They found that course instructors had to start at an almost zero level with respect to undergraduates' prior knowledge. On average the students knew 2,6 out of 32 common plant species. In another study, Lindemann-Matthies et al. (2011)

[4]The UN's sustainable development goals (2022): https://www.un.org/sustainabledevelopment/sustainable-development-goals/

investigated 690 preservice primary teachers' self-estimated knowledge of local wild plants and animals in four teacher education institutions in Cyprus, England, Switzerland, and Germany. One of the results showed that more than 70 % of the students could identify less than 11 wild plants by name and about 60 % could identify less than 11 animals.

The same trend seems to be true also for younger students in France. In a study with French schoolchildren, Ballouard et al. (2011) found that the schoolchildren's identification rate of local animals was low. The schoolchildren's consideration to protect animals was mainly limited to contents online, represented by a few exotic and charismatic species. According to the authors, the findings suggest a worrying disconnection between the school-children's and their local environment (Ballouard et al., 2011). Several other studies also point to such a disconnection (e.g. Kahn & Thea, 2017; Miller, 2005). Miller (2005) uses the notion 'extinction of experience' (with reference to Pyle, 1978) to describe the phenomenon as "a cycle of impoverishment that is initiated by the homogenization and reduction of local flora and fauna, followed by disaffection and apathy" (p. 431).

Together, the above-mentioned studies suggest that knowledge of local and common plants and animals is critically low among students across countries, educations, universities, and ages. There is an overall loss of experience of living nature due to the loss of local flora and fauna, but also due to what seems to be a blindness toward nature. This 'extinction of experience' means that many species have never existed to people, and as described by Ambjørnsen in the quote about birds: "They have never seen them. They have not even heard of them."(Ekelund, 2020, p. 1). Thus, there seems to be a connection between the loss of biodiversity, the loss of knowledge, and the loss of experience, that describe a 'cycle of impoverishment' (cf. Miller). The extinction of experience leads to a diminished ability to notice (the loss of) living nature, and finally, to a further loss of observational skills.

2.4 Science as a set of dynamic, varied, and historical practices

Promoting skills of precise observation is part of the core competencies in science education. Observational practices are fundamental in all sciences and through history scientific observers "have redefined what is under investigation by the way in which it is investigated. Observation discovers the world anew." (Daston & Lunbeck, 2011, p. 1). In other words, how a scientist observes defines what is under investigation, and by that, also how they understand science.

In science education literature, an overall question is: What might be meaningful ways of practicing science to know both science and nature? In the science education literature, both the terms scientific inquiry and scientific practices are used to describe the scientific processes. According to García-Carmona (2020), there has been a recent shift in terminology from scientific inquiry to scientific practices (e.g., in the influential NGSS), but learning science based on engaging in scientific practices seems to "differ substantially little from the inquiry-based science learning approach" (p. 456). The term 'scientific practices' is also present in the new Norwegian science curricula for primary and secondary school, where one out of five defined core-elements running through 1st to 10th grade is titled: "Scientific practices and ways of thinking" (Kunnskapsdepartementet, 2019). However, the characterization of these 'scientific practices and ways of thinking' is rather vague in the same science standards (Haug et al., 2021).

The problem of describing the processes of science, what it covers, and how it can be taught to students, seem to be persistent regardless of terminology. In this thesis, I will mainly use the term scientific practices to denote the processes of science. In the following, I will elaborate on 1) science as set of dynamic and varied practices, 2) science as historical practices, and 3) observational practices in science.

2.4.1 Science as a set of dynamic and varied practices

In the science education literature, there is an almost universal consensus that students should learn not only the content of science, but also what science is, its nature. However, there is much less agreement about what this nature is (e.g. Dagher & Erduran, 2016; Erduran & Dagher, 2014; Haug et al., 2021; Irzik & Nola, 2010; Osborne et al., 2003). Merleau-Ponty (2012) stated that science is the second order expression of the world. I want to explore: What are the characteristics of a scientific expression of the world? And how do observational practices correspond with such an expression?

For centuries, scholars have discussed the definition of science. According to Irzik and Nola (2010), so far, all attempts to define science rigorously have failed. Science is so rich, dynamic, and varied, that no set of characteristics is common to all scientific disciplines and shared only by them. It seems that the *nature* of science, meaning its essence, or the indispensable qualities of science, might not exist (Irzik & Nola, 2014). In science education, the difficulties with defining science have led to "the consensus view" about the nature of science (NOS), whose goal is to " teach students only those characteristics [of science] that are widely accepted "(Irzik & Nola, 2010, p. 591). According to Irzik and Nola (2014), research on NOS has revealed a significant degree of consensus that has been summarized in several ways (e.g. Abd-El-Khalick & Lederman, 2000; Lederman, 2007; Matthews, 2012; McComas et al., 1998; Osborne et al., 2003). Building on former research, like the NOS objectives formulated by McComas et al. (1998), Dagher and Erduran (2016) summarize the consensus view about NOS as a set of seven key aspects appropriate for school where one of the key aspects is "Observations and Inferences" (p. 148). The practice of observation is thus part of the characteristics of science on which there is wide consensus.

There is a large body of literature exploring and discussing the consensus view and each of the different aspects of NOS, how to teach it, and what views of NOS, teachers, students and scientists hold (Abd-El-Khalick & Lederman, 2000; Lederman, 2007). My aim is not to give a review on this literature here, but the interested reader may for instance turn to Erduran and Dagher (2014), who give a brief overview of the history of NOS in science education research, and also present the different debates concerning the limitations of the consensus-view. Instead, I will highlight some of the main points in the critique of the consensus view that are of special interest to my project, and also a possible reply to the critique (Irzik & Nola, 2010, 2014). One point of critique is that the consensus-view is not doing justice to the richness of science, portraying a too narrow picture of science, and seem to be blind to the differences among scientific disciplines (e.g. Erduran & Dagher, 2014; Irzik & Nola, 2010, 2014). Another point of critique is that the consensus-view about NOS gives an impression of science as fixed and timeless (Irzik & Nola, 2010):

> It gives the students the impression that science has no history and no room for change in its nature. However, history of science teaches us that

> its nature did change and evolve, albeit slowly. For example, more and more disciplines became mathematical in time and new methodological rules have been added to the stock of science (p. 593).

A science that is changing and historical in its nature is also in accordance with the statement that scientific observers throughout history “have redefined what is under investigation by the way in which it is investigated.” (Daston & Lunbeck, 2011, p. 1).

Irzik and Nola (2014) suggest using the idea of *family resemblance* developed by the philosopher Ludwig Wittgenstein[5] as an approach to describe science, instead of a model based on a consensus-view. Using the family resemblance approach (FRA), asking about the nature meaning the essence of science would be the wrong question. Rather, all the things we call science form ‘a family resemblance’ of partly overlapping items. There are no characteristics common to all sciences and at the same time definitional of science. For instance, although observation is common to all sciences, it is not definitional of science, because (obviously) not everything that involves observing is science. The other family-forming characteristics that accompany observation are what characterizes observation as part of a scientific discipline, for instance which questions you ask and how you classify your observations, and what aims and values you have for making observations. According to Irzik and Nola (2014) “what we need to do is to investigate the ways in which each of the sciences are similar and dissimilar, thereby building up from scratch polythetic sets of characteristics for each scientific discipline” (p. 1012). Based on the consensus on NOS, they give a structural description of eight categories of science and make an overall distinction between categories belonging to ‘Science as a cognitive-epistemic system’ of thought and practice”, and ‘Science as social-institutional system’. The four categories that belong to ‘Science as a cognitive-epistemic system’, are: 1. Processes of inquiry, 2. Aims and values, 3. Methods and methodological rules, and 4. Scientific knowledge. The four categories that belong to ‘Science as social-institutional system’, are: 5. Professional activities, 6. Scientific ethos, 7. Social certification and dissemination of scientific knowledge, and 8. Social

[5] According to Irzik & Nola (2014): «The idea of family resemblance was developed by the philosopher Ludwig Wittgenstein in recognition of the fact that not all terms can be defined in terms of necessary and sufficient conditions or by specifying essences or natures” (p. 1010).

values of science" (Irzik & Nola, 2014, p. 1009). Building on the family resemblance approach to NOS, Dagher and Erduran (2016) further develop the model with a visual representation in terms of the FRA-wheel (p. 155). In the FRA-wheel, the four categories belonging to 'science as a cognitive-epistemic system' constitute the inner circle. The four categories belonging to 'science as a social-institutional system' constitute the second circle with an additional third circle further reflecting the role of societal influences on the scientific enterprise. According to the authors: "The boundaries between the circles and the individual compartments of the FRA Wheel are porous, allowing fluid movement among its components" (p. 155).

Each of the categories in the FRA-model, either in 'science as a cognitive-epistemic system', or 'science as a social-institutional system' consist of an open-ended set of items. For instance, items belonging to the category processes of inquiry might be posing questions, making observations, collecting, and classifying data, formulating hypotheses, constructing and comparing alternative theories and models. And items belonging to the category aims and values might be: prediction, explanation, consistency, simplicity and fruitfulness (Irzik & Nola, 2014, p. 1004). Scientific disciplines consist of such items, which overlap among the different disciplines in various ways. Having items in common, like observational practices, different scientific disciplines may share some characteristics of these items, but not necessarily all. In other words, observing a rock, a chemical process or a living organism is not the same, and different contexts (like whether you want to draw or classify what you see) may invite to a variety of modes of observation.

Thus, using the family resemblance approach, science forms a complicated network of similar and dissimilar items and characteristics, overlapping and crisscrossing. The family resemblance approach makes it possible to portray both the richness, variation, and dynamics of science, demonstrating both similarities and dissimilarities between scientific disciplines, and also, how science changes. The idea of family resemblance "leaves this [*knowing science*] to a 'case by case' investigation" (Irzik & Nola, 2014, p. 1011).

2.4.2 Science as historical practices

Hadzigeorgiou and Schulz (2019) argue for narrative thinking as a bridge to understand science. They refer to Bruner (1986) and what he defined as two foundational modes of thought to understand the world; a *logico-mathematical* mode of thought that seeks to construct and model idealized systems of description and explanation and a *narrative* mode of thought that is concerned with life-likeness and creation of meaning, and which is context specific and particular. Although science obviously represent a logico-mathematical mode of thought, all scientific concepts and theories also have a human history of discovery and development. These histories often include personal stories of creativity, curiosity and wonder, and a language that can be figurative and metaphorical about ideas. However, by the time the discoveries enter the realm of text-book science, these stories are often neglected, and the concepts and discoveries are:

> …abstracted out of the historical matrix, while the language has shifted from narrative or lived story to depersonalized transmission and exposure. Too many textbooks create the false impression that science does not start as an exciting, arduous exploratory process but rather arrives as a "finished product" whose ideas, facts and equations are to be memorized and manipulated " (Hadzigeorgiou & Schulz, 2019, p. 4).

Telling stories that are context-specific and particular in science education 'case-by-case', may help the students to create meaning out of what otherwise would be abstract and generalized concepts and theories. It is a way of *knowing* science, instead of having *knowledge of* science, and may bridge the gap between the scientific expression of the world and the world how we experience it.

There have been several studies on the use of historical cases in science education to give students a better understanding of science, often presented as stories about historical persons and their explorations (e.g. Allchin, 2012; Conant, 1957; Hadzigeorgiou, 2022; Höttecke, 2012; Matthews, 2014). However, selecting stories that lead to an appropriate understanding of science and scientific practices is not straightforward (Heering, 2010; Klassen, 2009). I will come back to this in Chapter 8 where I discuss my selection of the historical cases in this project, and in Chapter 11 where I discuss how I have designed the teaching cases.

Here, I would like to emphasize how Elisabeth Cavicchi (2015) let “historical figures become virtual members in the classroom” (p. 185) in her science class at the Massachusetts Institute of Technology (MIT). Cavicchi applies a research pedagogy of critical exploration in the classroom developed by Elanor Duckworth (e.g. Duckworth, 2006), where both teacher, students and historical figures are co-explorers in the science class. Cavicchi (2015) writes:

> While instruction is often framed in antithesis—that of leading students by established routes to well-known outcomes—actual processes of learning are as complex and divergent as are the ways of past explorers (p. 186).

Cavicchi describes an open inquiry process about a chosen theme of, for instance, pendulums, mirrors and historical experiments (Cavicchi, 2008, 2011), where the students among other things are inspired by texts written by historical explorers, and historical figures, drawings and other materials. According to Cavicchi (2015) “teaching through critical exploration involves careful observation of the students and their relationships with each other and materials”, and “to provide an open and enticing environment that encourages curiosity to develop” (p. 187). The students develop their own questions and investigations in communication with each other, their teacher, and past explorers. In this way, the students respond to the historical explorations, which become part of their own investigations and experiments about a chosen phenomenon.

In my project, I use historical cases that demonstrate different modes of observation to explore living nature. The cases are meant to inspire the students to do their own explorations alongside the historical actors in each case, like Cavicchi describes above. To interact with the historical actors “as virtual members in the classroom” (Cavicchi, 2015, p. 185), while doing their own observations, may help the students to experience science as both varied, dynamic, and historical.

2.4.3 Observational practices in science

Daston and Galison (2010) refer to three codes for different epistemic virtues in the history of science when observing nature: ‘truth-to-nature’, ‘mechanical objectivity’, and ‘trained judgment’. In the science of the epistemic virtue of ‘truth-to-nature’, an illustration of for instance a plant, “aimed to portray the underlying type of plant-species, rather than any individual specimen" (p. 20). A depiction would be based on several observations of specimens to find the indispensable qualities (or essence) of a type or species. A science of 'mechanical objectivity' came after that of 'truth-to-nature' in the history of science, according to Daston and Galison (2010), and with this epistemic virtue descriptions of nature "aimed to quiet the observer so nature could be heard" (p. 120). It means to observe and describe, for instance, particular plants or animals with all their peculiarities, and with as little human intervention as possible. Observing in the virtue of trained judgement, was in turn a reaction to objectivity. It means to observe scientifically through an interpretive eye, in both making and using images of nature, where hunches and "leaps of imagination" (p. 311) may be guides to explanation. The three epistemic virtues represent different aims and values of science and seem to describe different views of what science is, or its nature.

To promote and train observational practices in science education may be a way of experiencing the dynamic and varied processes of science, which are both ongoing and historical. Observational practices interact with the phenomena you are investigating and will often characterize a specific scientific discipline. In the remainder of this section and the following section, I will therefore refer to the scientific discipline of biology instead of science in general.

In biology, observing, as a way of recognizing, describing, and classifying species in living nature, is one of the basic, yet complex, domains (Buck et al., 2019). Even though observational practices are fundamental in biology education, they are often underestimated by teachers, and neglected in the described science standards for school (e.g. Eberbach & Crowley, 2009; Merritt & Bowers, 2020). When the observation process is taken for granted, or ignored, it is assumed that observation just happens, which implies that observation is perceived as a (mere) passive process. However, observational practices in biology involve activities such as noticing and reasoning, asking the right questions, documenting, and having productive dispositions (Eberbach & Crowley, 2009). According to Eberbach and Crowley (2009) observation must be explicitly taught and practiced.

In biology, there is a long history of direct observation of the natural world, both to classify the entities of living nature, and to describe patterns and interactions between those entities, as in ecology. Observation-based ecology provides foundational knowledge of ecosystems, and "systematic observations of organisms and processes from an early age can help children develop ecological knowledge and skills, and deepen their connection to the natural world" (Merritt & Bowers, 2020, p. 619). Such experiences with living nature give students an opportunity to create meaning through interactions with others and the environment (Jørgensen, 2016).

The way in which observational practices in biology are taught and practiced in school, forms the basis for the students' process of knowing living nature. Furthermore, to practice observation is a way of inviting the students to engage in the world to create meaning. Thus, students in biology do not only develop skills and knowledge in classification and/or ecology, but also potentially in connecting with nature and creating (deep) meaning in these processes. In biology education, observing living nature has ethical aspects concerning both what the teachers bring into the students' field of perception, and how the teachers invite them to engage and participate, that I will come back to in Chapter 13. How teachers invite students to notice, describe, classify, and explain the entities of living nature demonstrates what they consider being good, important, or worthwhile to pay attention to.

2.5 The entities of living nature

To make the entities of living nature present and bring them into existence to the students we must be aware of what we mean by the entities of living nature, when using terms such as species and specimens. The terms are related; species is a type or kind of organism while specimen is a particular organism. The two terms exemplify the difference between a particular and observable entity, and a more general and theoretical entity.

Although species are referred to as real entities that exist in nature and that are discovered, described, protected, or counted, species are not entities that can be observed directly. We can observe individual organisms, and to a certain degree populations, but not species. Instead, 'species' is a theoretical term intended to represent an aspect of nature (Reydon & Kunz, 2019). The term 'species' represents types of living organisms that are variable, moving, growing, interacting, and evolving, and the boundaries between these types (or entities) may be vague. This leads to the well-known species problem, which is composed of the grouping and the ranking problem (Reydon & Kunz, 2019). The grouping problem emerges out of the question of what criteria makes a grouping of organisms into a species, irrespective of whether species are perceived as real entities or instrumental units. The ranking problem refers to the question of what makes a particular grouping of organisms into a species, rather than a genus or variety (Reydon & Kunz, 2019). The latter problem was already described by Darwin (1859) in the *Origin of species*:

> Certainly, no clear line of demarcation has yet been drawn between species and sub-species (…), or again between sub-species and well-marked varieties, or between lesser varieties and individual differences. These differences blend into each other by an insensible series; and a series impresses the mind with the idea of an actual passage (p. 41).

As Darwin points to in this quote, differences between species and varieties blend into series that seem to demonstrate forms of passages or transitions. According to the core principles of common descent and gradual evolutionary change in Darwin's theory of evolution, species change and evolve into new and different species. In other words, species are not fixed or distinct entities, neither in space nor in time.

The species-problem is demonstrated by the large number of different species concepts used in biology, which each referring to one or more causal factors to explain what species are (Reydon & Kunz, 2019). The three most prominent factors are: organismic traits (morphological species concept), reproductive compatibility (biological species concept), and common descent (phylogenetic species concept). There are also other factors, such as occupying the same niche (ecological species concept). Different definitions serve different purposes and may lead to different and incompatible groupings (e.g. Agapow et al., 2004). The term 'species' may even be understood as a homonymic term "that covers a considerable diversity of ways of grouping organisms in different contexts of work" (Reydon & Kunz, 2019, p. 628). To resolve the question of what a species is with one answer has not turned out to be productive, at least not so far (Hey, 2001). Thus, classification in biology is different from classifying in other fields of science. In biology, classification may be both a tool and an aim of practicing science: it serves to make diversity manageable, but may also, for instance, reflect theories of common ancestry as in phylogenetic classification) (Reydon, 2013). According to Morante and Rossi (2016) “the existence of many possible classifications is a typical feature dealing with complex systems”(p. 179). In their article they argue for a novel interpretative paradigm in the study of living systems based on the notion of ‘complexity’.

In education, Reydon (2013) suggests that it may be more important to understand why there is a plurality of species concepts in biological science and what this means for biological practice, rather than focusing on the definitions per se. The species problem can be used in education to discuss crucial aspects of the nature of science (Nyléhn & Ødegaard, 2018; Reydon, 2013). For instance, it can be used to demonstrate that science isn’t a unified enterprise, but a large variety of fields with different aims, methods, and ways of classifying. Scientific methods in biological systematics do not follow a simple stepwise method based on experiments where theories are proven or disproven (as often presented in school textbooks). Instead, it is often a question of the explanatory power of a theory or concept. The explanatory power of a species concept depends on which group of species the concept is applied to.

The species concept illustrates how humans invent categories in science and then compare them with their observations, and it seems that humans tend to “give names to categories even when reality is continuous” (Nyléhn & Ødegaard, 2018, p. 694). In education, a mismatch between what students observe in nature (e.g., a particular specimen), and our theories and categories (e.g., a species), may be an opportunity “to trigger thoughts, open questions, and meaningful discussions” (p. 709), which might provide a more nuanced picture of scientific practices in general and even enrich the phenomena in nature.

According to Buck et al. (2019), identifying plants (or animals) requires both declarative species knowledge and taxonomic concept knowledge, and students need to build a link between theoretical scientific understanding and the practical and complex task of identification. An essential part of building this link is to practice observational skills. In an explorative study, a marine biologist worked together with 10th graders to practice observation to identify species of deep sea snails (Bardy-Durchhalter et al., 2013). One of the difficulties that emerged was for the students to distinguish the intraspecific variability of the dominant species from features exclusively belonging to other species. The biologist had made working material for the students with photographs of the different snails and assumed that “most species can be recognized immediately by looking at them” (p. 51). However, this was not the case, as students found features that were repeatedly refused by the biologist, and she tried to implement, in her view, more effective ones. During the lesson, students struggled to find helpful diagnostic characteristics, and establish a common understanding of the descriptions of biological structures. The study exemplifies the challenges with applying the species concept in education, and the inherent problem of grouping and ranking species becomes visible. When it comes to the practical task of identification, it is a question of evaluating which visible characteristics or features are significant in the categorization of organisms as a species. As Darwin wrote, differences blend into each other, and Bardy-Durchhalter et al. (2013) emphasize the need to point out to the students that diagnostic characteristics are tools. According to Chambers (2012) the problem, in practical terms, “comes down to the need to impose a discrete classification (taxonomy) upon an essentially continuous phenomenon” (p. 756).

Thus, the species problem and the many possible classifications of living nature demonstrate essential features with the phenomenon of living nature, as being continuous, dynamic, and complex. What we perceive as entities of living nature is not given and depends on our mode of observation. The complexity of living nature invites to a variety of observational practices and understandings of what "an entity of living nature" is. These varieties, of both practices and entities, complement each other, rather than exclude one another.

3 Central concepts, research questions, and structure of the thesis

3.1 Central concepts and scope

In this study, I investigate the phenomenon of observing living nature in history, teaching, and learning. In my research, I understand *teaching and learning* in terms of *Bildung*. In the German and Scandinavian tradition which I am part of, the process of *Bildung* aims to enable the students to create meaning, form the self, and participate within society (cf. Dewey, Wagenschein, and Klafki). I further build on Klafki's concept of categorical *Bildung* and his didactical analysis (Klafki, 2006) and understand a teaching design to include both a specific content and methods for exploring. In my study, *didactics* (*Didaktik*[6]) refer to how the teacher design their teaching to promote *Bildung* in their students[7].

When I investigate the phenomenon of observing living nature in the context of teaching and learning science in primary school, I refer to both a specific content and different methods for exploring. The content is delineated by the term *living nature* and designate all parts of nature consisting of living beings. In science, this content belongs to the scientific discipline of *biology* and partly overlap with concepts like biodiversity, living organisms, and species. I have chosen to use the term *living nature* to avoid these more theoretical concepts. Living nature seem to better describe phenomena that can be experienced and observed, while the more theoretical concepts like biodiversity, living organisms, and species cannot be experienced or observed directly in nature. Living nature includes human beings, however in this thesis, when I use the notion of observing living nature, I refer to humans observing living beings in nature that are non-humans.

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[6] From greek didaktikós, 'skilled in teaching'. From Wiktionary, the free dictionary: https://en.wiktionary.org/wiki/didaktik

[7] It is important to notice that in the English language the adjective *didactic* has a different meaning than how I use the term in my thesis. According to an English dictionary didactic means: "intended to teach, especially in a way that is too determined or eager, and often fixed and unwilling to change". From the Cambridge Dictionary: https://dictionary.cambridge.org/dictionary/english/didactic.

In the Norwegian primary school, which is the context of this study, *biology* is not a separate subject, instead, biological topics are part of a general subject of *science*. In Norwegian the name of the subject is *naturfag* which literally means the subject of nature. Content that describes the non-living parts of nature belong to the scientific disciplines of geology, chemistry, and physics. However, the Norwegian science curriculum for primary school is structured by core elements of the subject and not scientific disciplines, and some topics in the science curriculum go across the disciplines (UDIR, 2020). Thus, in this thesis, I consider the topic of living nature as belonging to the general subject of science in primary school and will therefore refer to research on *science education* and/or *science teaching and learning* most of the time.

The phenomenon of observing living nature in the context of teaching and learning science also refer to practices and methods of exploring living nature. In this thesis, I use *observation* and *observing* in an extended meaning. *Observing* is more than seeing, it may include for instance hearing, smelling, and touching. Further, I understand observation phenomenologically as a way of communicating with and participating in the world to create meaning as human beings. A related term is *attention* that comes from Latin *attendere*[8], literally meaning to stretch toward. Paying attention may be used in terms of taking a position and focusing on something as in observation. *Attention* also means consideration and "observant care" in English and entails an aspect of receptiveness or caring absorption with what you pay attention to (this will be elaborated in Chapter 13).

In science education, observation is part of learning scientific practices and scientific skills. Scientific practices are related to and sometimes used interchangeably with the term *inquiry* in the science education literature. However, scientific practices seem to increasingly replace the term inquiry (e.g. Gericke et al., 2023; Rönnebeck et al., 2016). In my thesis, I use the term *scientific practices* to describe the processes of science, both the historical and ongoing processes. Instead of defining scientific practices in a final form, I present four cases from the history of science that demonstrate different and

[8] "Directly from Latin noun of action from past-participle stem of *attendere* "give heed to," literally "to stretch toward," from ad "to, toward" (see ad-) + tendere "stretch" (…) The meaning "consideration, observant care" is from 1741". From the Online Etymology Dictionary: https://www.etymonline.com/word/attention

complementary observational practices in science. I will further discuss and compare questions, ways of knowing, and what kind of knowledge that comes out of these cases to elaborate on the meaning of scientific practices both historically (Chapter 11) and in teaching and learning (Chapter 14). Furthermore, I build on Dewey's concept of an educative experience as an experience that enhances the learner's sensitivity and responsiveness and enables the growth of further experience (Dewey, 1938). Learning scientific practices and observational skills, I understand as practicing observation and gain experiences that enables further exploration.

Phenomenology is the study of phenomena, or a study of " the world as we immediately experience it pre-reflectively rather than as we conceptualize, categorize , or reflect on it" (van Manen, 2016b, p. 9). According to Heidegger (1962), *phenomenon* "signifies that which shows itself in itself", and *phenomena "*are the totality of what lies in the light of day or can be brought to the light" (p. 51). Phenomena may also be identified as *entities*, and Heidegger continues: "Now an entity can show itself (*von ihn selbst her*) in many ways, depending in each case on the kind of access we have to it." (p. 51). In this thesis, I refer to phenomenon in the meaning of a thing or entity as it shows itself in our experience. To avoid using the concept of an object as something opposed to a subject in these experiences, I use *things* and *entities* as a deliberately vague notions of what is brought to the foreground when we are observing. Things and entities are what we perceive as delineated or fixed in these experiences and which constitute and furnish our environment. Phenomenologically, things are a result of how you make the world intelligible (e.g. Heidegger, 1962). When I refer to the phenomenon of *observing living nature* in my study, this includes both the phenomenon of observing and the phenomena in living nature. In other words, I mean to describe how observing living nature is experienced by teachers and students. These experiences include different practices of observation, *things/ entities* in living nature, and how the practices and things affect one another. The phenomenological approach in this study will be further elaborated in Part II.

3.2 Purpose and research -questions

The purpose of this study is to phenomenologically explore the practices of observing living nature in history, teaching, and learning, and to discuss potentials and constraints with teaching and learning observational practices in primary school.

I will explore how the phenomenon of observing living nature, understood as various attentional practices in science education, will help students acquire skills and knowledge in *response to* living nature and give them a more nuanced familiarity with the natural world. I will seek to understand how different modes of observation are formed by what you find meaningful, valuable and/ or important, and how these positions will depend on what you are observing, your former and present embodied experiences and affections, as well as your cognitive intentions with the observation. I will investigate how the implications for science education, shifting from a transmission of knowledge to attentional practices, are not only didactical, but also existential and ethical. Existential because it is only through being active and engaging in the world that students (and everybody else) can understand what being is and thereby make the world intelligible. Ethical because attention as a kind of receptiveness or concernful absorption with the world involves care. Education as attentional practices *in* and *with* living nature has the potential to bring the manifold living phenomena in nature into existence for the students. I will explore how such an education of attention in terms of *Bildung* may enable the students to create meaning and form the self.

The overall research question in this study is:

> What is the nature and meaning of observing living nature in science education in primary school?

This leads to the following four subordinate research questions:

1. How might cases from the history of science be designed to strengthen teachers' and students' observational practices and knowledge about living nature?
2. How do teachers experience the practice of observing living nature in the context of teaching and learning science in primary school?

3. How do 5th grade students experience different modes of observing living nature demonstrated through four cases from the history of science?
4. What are the potentials and constraints with teaching and learning observational practices in primary school?

To phenomenologically investigate the practice of observing living nature in history, teaching and learning means to explore observation as a way of engaging in the world. In this case, the experience of both being in an active mode of observation, and at the same time being receptive towards living nature, is essential in this study. As an educational tool, phenomenology means to practice careful observation as a way of learning. As a research method, phenomenology means to gain rich contextual descriptions of lived experience with the phenomenon and reflect on and interpret the nature or meaning of this experience.

3.3 Structure of the thesis

To answer the overall question and the four subordinate research questions I shall proceed as follows. First, in Part II, I will go on to describe what I mean by a phenomenological approach in this thesis. In Part III, I will describe research design and the methods I have used to collect and analyze data to answer the research questions in different phases of the study. In Part IV, I will present the results of the analyses in terms of four historical cases, and themes that describe the teachers' and the students' experiences with observing living nature. In Part V, I will discuss implications for teaching and learning science in primary school, point towards a possible fifth teaching case, and reflect upon my own process as a researcher.

PART II: A phenomenological approach

The overall aim in phenomenological research is to come to an understanding of the significance of an aspect of human lived experience. In my research project I wish to explore the phenomenon of observing living nature as an aspect of human lived experience in the context of teaching and learning science in primary school.

My aim in this part is to describe what I mean by a phenomenological approach, according to the following four aspects: 1) as an ontology (as a foundation for knowledge) 2) as an epistemology (as a way of knowing), 3) as an educational practice (as a way of teaching and learning), and 4) as a research-method (as a way of structured inquiry). In my project these four aspects are closely connected. A phenomenological approach to what 'being in the world' means (ontology) has implications for how you understand knowledge and knowing (epistemology), and the way in which you understand knowledge and knowing has implications for how you understand and practice both education and research.

4 Ontology – being world-disclosers

> I looked out the window, I saw the clouds, the landscape beneath them, and I got an intense sense of the world. It was as if I hadn't seen it before. The world was a planet covered in gases. That insight, which is indescribable, filled me with happiness, but also impatience and eagerness. The moment passed, the plane landed, and I took the boat out to my grandparents, but I never forgot. To myself, I called it the 'world feeling'.[9] (Knausgård, 2013; my translation from Norwegian)

4.1 What makes the world intelligible?

Observing living nature is part of your being in the world, which means it is normally in its everydayness something you experience and not something you reflect upon. It means that you primarily make sense of things you observe in nature while being active and by coping with different tasks. Being in the world, or what Heidegger calls *Dasein* (= being there) in his influential book *Being and Time* (Heidegger, 1962), is the primordial condition. *Dasein* is the background that makes the world intelligible in the first place. Ontology belongs to the philosophy of metaphysics and means the study of being, dealing with questions like which entities exist at the most fundamental level. To describe being in the world as the primordial background that makes the world intelligible is a way to understand ontology. In this section I explore how this ontological understanding elucidates the phenomenon of observing living nature and what we perceive as 'things' in nature.

When walking in the woods there are almost infinite things you may notice along the path. You make sense of what you see in different ways depending on your activity, and your prior knowledge and experience. For instance, you may be absorbed by the activity of picking blueberries or chanterelles, or you may be an

[9] The original quote in Norwegian: "Jeg så ut av vinduet, jeg så skyene, landskapet under dem, og jeg fikk en intens følelse av verden. Det var som om jeg ikke hadde sett den før nå. Verden var en planet dekket av gasser. Den innsikten, som er ubeskrivelig, fylte meg med lykke, men også utålmodighet og higen. Øyeblikket gikk over, flyet landet og jeg tok båten ut til mine besteforeldre, men jeg glemte det aldri. For meg selv kalte jeg det «verdensfølelsen."

ornithologist especially receptive towards the birds singing in the trees, or you may be a five-year-old eagerly searching for insects underneath rocks and logs. In all these cases, the concernful absorption with the activity makes the woods withdraw to the background, and you are directed towards the things that are part of the activity in question. In Heidegger's words the "concernful absorption" (p. 101) in whatever activity has a function of discovering, and:

> (…) it is essential to this function that, depending upon the way in which we are absorbed, those entities within the world which are brought along [beigebrachte] in the work [or activity; my comment] and with it remains discoverable in varying degrees of explicitness and with a varying circumspective penetration. (Heidegger, 1962, p. 101).

Whether you are involved in the activity of listening to birds or picking blueberries, certain entities within the world are brought along. Depending on whatever activity is intelligible to you, some 'things' become significant. Another important aspect of your absorption in activity is that it also allows you to not pay attention to other things.

However, although you may be involved in different activities when observing living nature, the activities are, Heidegger claims, always part of an overall background familiarity with the world which makes everything intelligible and organizes all activity (Heidegger, 1962, p. 119). In your primordial being in the world (*Dasein*), you already have an ability to cope with entities in the world, and this broad familiarity is foundational and makes it possible to intentionally bring things to the foreground, in the first place. The phenomenon of 'world' is a mode of being and what Heidegger calls 'worldhood': "Worldhood itself may have as its modes whatever structural wholes any special 'world' may have at the time; but it embraces in itself *a priori* character of worldhood in general" (Heidegger, 1962, p. 93). This *a priori* character of worldhood is the foundational familiarity with the world that makes you know your way around and makes it possible to cope with different tasks.

4.2 Knowing the world

In Chapter two of *Being and Time* (1962) Heidegger explores what 'being-in-the-world' means:

> Knowing the world – or rather addressing oneself to the world and discussing it – thus functions as the primary mode of being-in-the-world, even though Being-in-the-world does not as such get conceived (Heidegger, 1962, p. 85).

The phenomenon of observing living nature refers to the experience of being both present and receptive towards living nature, thus "addressing oneself to the world", and it seems to belong to the primary mode of being-in-the-world. According to Heidegger's quote, in its primary mode, 'being' is an active turning towards the world, or, in other words, being is the same as knowing the world. In your primordial being-in-the-world (*Dasein*), you make sense of the world in activity by using things in the world. However, the activity is somehow hidden to you because it is something you do, and in Heidegger's words "being-in-the-world does not as such get conceived". When you are really involved you don't reflect on having an experience, you just feel the flowing moments of life. In other words, in your primary mode of being you simply are what you do, and there is no outer or inner world, nor subject or object, only being. It means that your acting in the world is of a more fundamental character than your knowledge about the world, and involvement in activity is prior to detachment and theorizing about the activity. You can encounter things in the world without analyzing them, just using them, and you may know how, without having knowledge of them. For instance, you can use a doorknob or a pair of binoculars without paying attention to their properties.

In my understanding, being an ornithologist absorbed in the activity of listening to birds is one way of being, another is being a person picking blueberries for eating, or a child looking for insects. Likewise, I could list manifold ways of being in the woods (or being-in-the-world). A forest (or the world) has infinite aspects that you can experience, depending on how you address yourself to the world. In these experiences, depending on the activity, certain things become significant, whereas others do not. For instance, only by listening to the birdsong is it possible to distinguish between the common chiff-chaff (*Phylloscopus collybita*) and the willow warbler (*Phylloscopus trochilus*), because in visual appearance they are virtually identical. If listening to birdsong in the woods is a meaningful and intelligible activity to you, as part of your 'being-in-the-world', the two different bird species may become significant and separate things, otherwise they are not. Likewise, if picking blueberries is a meaningful activity to you, and you pick them in order to eat them, it is likely that similar-looking blueberries (*Vaccinium myrtillus*) and bog bilberries (*Vaccinium uliginosum*) become significant and separate things to you, because they taste differently, but otherwise they are probably not. Things in nature becomes present to us in and through activities that are meaningful, however, if we are deaf and blind to those things, they do not exist.

When different birds, or berries, become present to you as entities with certain properties, it is a process of 'deworlding' in the sense that they are brought to the foreground and fixed. While binoculars that you have brought along to observe the birds with, or a blueberry rake for harvesting blueberries, are most likely things you use without paying attention to its properties. In that sense the binoculars, or the blueberry rake, are transparent to you. Heidegger separates between these two kinds of being of things, where the first is what he calls 'present-at-hand' and the second 'ready-to-hand', or simply equipment. The binoculars, or the blueberry rake, working at their best, is an equipment you know how to use without having to pay attention to its properties. Equipment is essentially something you use 'in-order-to', and "in the in-order-to as a structure there lies an assignment or reference of something to something."(Heidegger, 1962, p. 97). You use the binoculars 'in-order-to' observe birds, or the blueberry raker 'in-order-to' pick blueberries.

To a five-year old searching for and collecting insects in the woods, different insects, and also centipedes and earthworms probably become present entities, or in other words, things that are 'present-at-hand'. In the activity, earthworms, for instance, may become present to him as something that he recognizes with certain properties, different from insects. In contrast, the child uses a collecting bucket and shovel as 'ready-to-hand' equipment without paying attention to their properties, as long as they fulfil their purpose. I imagine that once you become for instance a skilled ornithologist, the birdsong may be something 'ready-at-hand' as well, as a kind of equipment you use 'in-order-to' map different birds in the woods. You don't have to pay attention to the properties of the birdsong itself, you simply recognize it as a common chiffchaff or a willow warbler.

To observe living nature is part of your primordial 'being-in-the-world' (*Dasein*). In and through activities, such as listening to birdsong, picking blueberries, or looking for earthworms, you address yourself to the world, and entities within the world are brought along (*beigebrachte*, cf. Heidegger p. 101). Depending on your mode of observation, different things, like for instance the common chiff-chaff, the willow warbler, blueberries, or earthworms, become present to you. In the process the world is dis-closed, and, at the same time, the things that become present to you are 'de-worlded'. The things you see in the world are conceived as entities with fixed properties, although they are dis-closed "in varying degrees of explicitness" depending "upon the way in which we are absorbed" in an activity (cf. Heidegger, 1962, p. 101). The way in which you are absorbed depends on your primordial being in the world and how you make the world coherent and meaningful. Thus, it is only by addressing yourself to the world that you can understand what being is, and, at the same time, make sense of what you meet in the world, and thereby being a world-discloser.

5 Epistemology - observation as a way of knowing.

> The world is not what I think, but what I live (Merleau-Ponty, 2012)

5.1 The living body as the subject that observes

When observing living nature, perception and embodiment are basic to the experience. In this section, I explore the body phenomenological perspective described by Merleau-Ponty in *Phenomenology of Perception* (2012), how he understands perception and knowledge, and how this may be helpful to understand observing living nature as a practice and a way of knowing.

Observation is a way of knowing by a practice of paying attention to the world. Epistemology means theory of knowledge and describes ways of knowing. In my thesis, the phenomenon of observing living nature can be understood as an epistemology that is produced through various observational practices. Observational practices may be, for instance, inductive, deductive, holistic, analytical, objective, subjective or artistic, depending on what questions you ask, what and how you see, and what narratives you tell. The way in which scientists have observed nature has influenced the kind of questions they asked and the kind of knowledge they formulated, and accordingly what science was all about (Daston & Lunbeck, 2011). Thus, how you practice observation and perception is foundational for how you understand ways of knowing, and for how you experience the world.

Merleau-Ponty (2012) describes "sensing as coexistence" (p. 216) with the world and sensations as "enveloped with a living signification" (p. 217). He further writes:

> In perception, we do not think the object and we do not think the thinking, we are directed toward the object, and we merge with this body that knows more than we do about the world, about motives, and about the means available for accomplishing the synthesis (p. 248).

This means that your body has a history of experiences, and it positions itself in the world according to what is felt as being significant and meaningful due to this history. Observation is understood existentially as a way of engaging in and communicating with the world. It is about how you perceive the world, but also about how you perceive yourself in it. Observation is neither a passive perception of given objects based on pure sensual impressions, nor simply a perception of representations as you conceive of them with your intellect. In both cases, the body itself remains an object according to Merleau-Ponty (p. 56/ 83), either as a pure mechanism, or as a neutral vehicle for the mind floating above the world. Merleau-Ponty's (2012) main point in *Phenomenology of Perception* is that we must be aware that the living body is *the subject* of perception. We perceive the world as living organisms *in* the world.

To describe the experience of observing living nature with the body as the subject, we must go from a description from the outside to a description from the inside. A description based on a mechanistic explanatory model, would be a description from the outside where the subject that makes the experience remains unknown to us. From the inside, the perceptual field is our interface with the world. Merleau-Ponty describes observation as a coexistence with the world which is developed and synchronized with the world we live in: "The subject of sensation is a power born together with a certain existential milieu; or that is synchronized with it" (Merleau-Ponty, 2012, p. 219). My nephew is five years old and very interested in all kinds of animals. He eagerly collects insects, snails, millipeds and earthworms. He acquires experiences by actively searching for organisms and learning their names. He sees, hears, and grasps what he encounters, and he has a lot of questions. Because he actively seeks out this type of experience, these phenomena will probably become richer and increasingly more nuanced to him, containing more associations, memories, and expectations. How he experiences these phenomena will change as part of his participation in the world. These experiences will be transformative in that they change both his perception of the world and of himself in it. This means that observation is never just a pure impression or impulse, it is about interaction and communication. As you gain experience of what is significant in the world, the way you absorb your surroundings changes. There is no linear dependence between stimulus and receptor, according to Merleau-Ponty it is more like an arc (intentional arc) that goes through you and back to what you are looking at. This arc ensures a meaningful connection and "creates a unity of the senses, a unity of the senses with intelligence, and the unity of sensitivity and motricity", and it contains your previous experiences, environment, physical situation, ideology, and morality (Merleau-Ponty, 2012, p. 137). A stimulus can initiate a reaction and as a living body you pick up the meaning of that stimulus, but there is no pure representation, and the meaning can change in the face of several experiences. This is because the body is first and foremost an organism and not a mechanism. The underlying purpose is always to get the best possible grip as a participant in the world. Everything is taken in based on previous experiences, and the phenomena you experience must be understood as part of your 'being-in-the-world' (cf. Heidegger).

5.2 Observation, reflection, and knowledge

Merleau-Ponty uses the term 'phenomenal field' about the field where we make all our experiences, and which is a transcendental field underlying reflection. To Merleau-Ponty, the word 'field' signifies that reflection never has the entire world and all units in it before its gaze, and "that it only ever has partial view and a limited power." (Merleau-Ponty, 2012, p. 62). It means that we can never place ourselves outside of the world, the phenomenal field is our world in which we are immersed.

According to Merleau-Ponty (2012), to understand reflection and knowledge you must be aware of the natural state that reflection replaces (p. 63). Merleau-Ponty describes the pre-reflective view as a horizon that lies behind all our experiences and where things and ideas are born (p. 228). Pre-object phenomena, or rather 'pre-things phenomena', are those that can become things, but do not yet appear to you as such. This means that in a pre-reflective mode you have an open relationship with the world that is indeterminate and undefined. However, as Merleau-Ponty claims, you will constantly try to align yourself to organize the indeterminate, like when you unconsciously adjust distance and position in front of a painting to see it in the best possible way (p. 315 -316). As you focus and organize, you go from a pre-reflective mode to a reflective mode and things emerge. The body will perceive what we see as determined things, and the original, open relationship with the world "stiffens" and is delimited (Merleau-Ponty, 1994, p. VII)[10]. This seems to be in line with Heidegger's notion of

[10] From the introduction written by Dag Østerberg.

entities that are ‘brought along’ (cf. Heidegger, p. 101) with and in activity, where ‘you address yourself to the world’, and where entities become present to you as things with fixed properties during the process.

When walking in a forest, you may sense it in an open way, hearing birdsong, feeling the moisture from the trees, smelling soil, and seeing green colors, and having an experience of being in the forests without reflecting on what things are there. Often, however, you will seek to organize the indeterminate experience of being, and in a reflective mode you can define what you experience as forest, as birdsong or as moisture from the trees. In my understanding, this organization may be more or less nuanced depending on previous experiences. For instance, a child may be able to organize the experience as being in the forest, without necessarily having a concept of trees or birds. A biologist, on the other hand, with a lot of forest experience and knowledge of trees, will be able to define at a glance what kind of forest it is, which birds are singing, and in addition, have many associations, memories, and expectations that probably will make the experience more nuanced.[11]

In the forest, either as a child or a biologist, you may also choose to focus on and root yourself in a specific phenomenon. For instance, you may turn your attention towards a beetle crossing the path in front of you and see more details than when your gaze took in the whole landscape. This attentional turning is a movement where you closeout the landscape and open yourself to a specific object, a process in which the rest of the forest becomes part of the horizon. You position yourself to find a distance and an angle that you experience as being the best possible for observing the beetle. In a way, the beetle invites you to observe it in a certain way and at a certain distance, and you respond by positioning yourself, Merleau-Ponty (2012) claims, as a body *in* the world.

> For each object, just as for each painting in an art gallery, there is an optimal distance from which it asks to be seen - an orientation through which it presents more of itself - beneath or beyond which we merely have

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[11] In line with Heidegger’s notion of ‘concernful absorption’ where ‘things’ within the world are brought along in and with an activity, but where ‘things’ “remains discoverable in varying degrees of explicitness and with a varying circumspective penetration.” Heidegger (1962, p. 101).

> a confused perception due to excess or lack. (Merleau-Ponty, 2012, p. 316)

The beetle is perceived as having a constant shape, size, and color, although the pure sensory impressions of both color, size and shape may vary. Its size may vary with your distance to the beetle, its color may vary with the light, and its shape may vary with the angle from which you observe it, yet you perceive the beetle as an entity with fixed properties. The distance between the living body and the observed phenomenon “is not a size that increases or decreases, but rather a tension that oscillates around a norm”, and an oblique orientation is “experienced as a disequilibrium” (Merleau-Ponty, 2012, p. 316). In other words, in the attentional turning towards the beetle crossing your path, you seek to find a position, or equilibrium, in which the beetle ‘presents more of itself’. In the same way as there is an optimal distance and angle between your body and the object, there are light conditions where you also experience that the beetle will ‘present more of itself’. If the light conditions change, your body orients/aligns itself accordingly, without you reflecting on it. The body adapts to the new environment and the new color conditions within, and you still perceive the colors and the object as constant (Merleau-Ponty, 2012, p. 325). For instance, if you move the beetle from daylight outside to a more yellow electric light inside, you will still perceive the beetle as a constant entity with fixed properties and colors. Thus, your body's openness to the world ensures that things are perceived as constant in terms of size, color, and shape. The body constantly seeks balance and stability if things appear blurred or undefined. This ability of the body makes the world coherent and is the underlying horizon for all experiences.

Observation as a way of knowing means to understand observation as an active process, although not necessarily as an intentional practice, but rather as a ‘concernful absorption’ (cf. Heidegger, p. 101). Observation as an attentional practice means that there is a complementary relationship between the observer and the observed, and that observation always takes place in a particular body and within a specific context. It is not something that just happens, like in a mechanism. You position yourself, as a *living* body *in* the world, in such a way as to experience that the things you observe show themselves. Whether you observe a rock, a chemical process or a living organism is not the same, and different contexts, like whether you want to draw or classify what you see for instance, may invite to a variety of modes of observation. Reflection and knowing, based on observation, are processes of organizing and articulating of what you see. In the process the world “stiffens” and what you perceive are simply things in the world. Although the observed may be seen from different angles and positions, the living body ensures coherence.

6 Education – a practice of attention

> The curious investigator, who wants to examine the properties of insects, can hardly have a greater pleasure anywhere. Just examine: the rostrum of snout-beetle, the horns of stag-beetle, the antennae of longhorn beetle, the joints of blister-beetle, the wings of an earwig (…) the life of an ephemeron, an anthill, the trap-fall of an antlion, a spider's web (…) and the metamorphosis of nearly all insects. (Carl von Linné, 1735)

6.1 Recognizing living nature

A phenomenological approach to observing living nature in education means to address yourself to the living world (cf. Heidegger*)*, to participate in observational practices as a living body (cf. Merleau-Ponty), and to learn by experiences of attention. Experiencing is understood as gaining skills and knowledge by repeated trials.[12] However, the link between experience and education is not straightforward. In the book *Experience and education* John Dewey (1938) writes:

> Experience and education cannot be directly equated to each other. For some experiences are mis-educative. Any experience is mis-educative that has the effect of arresting or distorting the growth of further experience. An experience may be such as to engender callousness; it may produce lack of sensitivity and of responsiveness. (p. 25).

In other words, an educative experience is one that enhances the learner's sensitivity and responsiveness and enables the growth of further experience. To educators, the challenge "is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences" (Dewey, 1938, p. 28). In this section, I explore the meaning of an educative experience when learning to recognize living nature, and which potential consequences this meaning has to educators.

[12] 'Experience' comes from latin *experientia: ex*- 'out of' + - *peritus* 'experienced, tested'. From Online Etymology Dictionary: https://www.etymonline.com/word/experience

When learning biology, the skills to recognize, describe and classify species, are but a few, of the basic, yet complex, competencies. In English, to recognize means at least two things: first, *to identify* someone or something from having encountered them before; know again (from latin *recognoscere*: *re-* 'again'+ *cognoscere* 'learn'), and second, *to acknowledge* the existence, validity, or legality of someone or something[13]. In other words, to recognize plants and animals is both to know and identify them and to acknowledge their existence. This dual meaning of 'recognizing living nature' implies an open awareness where you let what you observe (e.g., plants and animals) to a large extent speak for itself. Thus, to recognize living nature is to gain skills and knowledge by both identifying and acknowledging plants and animals through experience.

6.2 Learning to identify living plants

Identifying plants and animals involves more than recalling their right names. In my experience, both as a biology student and biology teacher, identification of plants and animals is a practical task where skills and knowledge are gained by repeated trials and by gradually developing an understanding of a practice of classification. Following Dewey, the question in biology education is how to facilitate for experiences that enhance students' sensitivity and responsiveness to plants and animals and enable the growth of further experience in the students. When learning to identify a plant species, for instance red clover (*Trifolium pratense*), you must study several specimens and find overall typical features that are specific for this species. The process involves recognizing features that are common to all red clovers (although different specimens may have variations), and which, at the same time, separate red clovers from all other plant species. To identify red clover in nature you need to know which features to focus on, and in addition, be able to compare and separate between plants species that are similar. In the process, you will need to learn how to see and recognize details (like different parts of the flower), but also to become familiar with variations within the species and how the plant grows and changes (which is essential to all living organisms). This complexity explains why there is a lot more to identification than merely recalling a plant's right name.

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[13] From Google's English dictionary provided by Oxford Languages: https://languages.oup.com/google-dictionary-en/

When learning to identify a plant species, an experience might be mis-educative if it closes (instead of opens) the world to the student. If teachers simply tell their students the names of different plants by pointing them out, without giving the students a chance to practice observation and gain skills and knowledge by repeated trials, it is likely that the growth of further experience is hindered. The experience is limited to recalling the right name of an organism instead of enhancing the students' sensitivity and responsiveness to the living beings in nature. The experience is mis-educative because the knowledge gained is static and absolute and gives little room for expansion. Another way in which such an experience might be mis-educative is if the study of plant species is mainly limited to the classroom and the study of pictures (either drawings or photos/films) of plants in a textbook or on a screen or blackboard. Such pictures will always be depictions where an artist or photographer has already decided what to emphasize, or what matters or not, when identifying plants. In studying a picture of a plant, for instance, it is decided which plant are chosen in the first place, what life stage is depicted or what part of the plant is emphasized, whether the plant's environment or interaction with other species is part of the picture, and whether the plant is presented together with similar plants to compare specific features. Either way, the plant is taken out of its context, and something is lost. The experience might be mis-educative if the students are not given the chance to explore the variations, dynamics, and diversity of plants in nature. The experience will probably 'distort the growth of further experience' (cf. Dewey) if the connections between the experiences made by the students in the classroom and in nature are broken or never even established. Although the students have engaged in classroom activities, a missing or broken link, will make it difficult for them to recognize living plants in nature. If students do not actually engage in the activity of recognizing plants in nature, they will probably not become significant entities to the students (as part of their being in the world), instead they will stay part of an overall background.

All experiences in some way or another are affected by earlier experiences and modify the quality of future experiences. Dewey (1938) calls this the principle of continuity of experience and uses this as a criterion by which to discriminate between experiences which are educative and those which are mis-educative. According to Dewey, the continuity of a mis-educative experience may operate in a way that limits later capacity for growth, while:

> “On the other hand, if an experience arouses curiosity, strengthens initiative, and sets up desires and purposes that are sufficiently intense to carry a person over dead places in the future, continuity works in a very different way. Every experience is a moving force. Its value can be judged only on the ground of what it moves toward and into.”(Dewey, 1938, p. 38).

To enable the growth of further experience, the educator should try to create conditions for experiences ‘that arouse curiosity, strengthen initiative, and set up desires and purposes’ in the students. More specifically, when learning to identify plants, the educator should try to give the students experiences that motivate them to further engage in exploring plants. This could be done by giving the students a chance to engage in the activity of recognizing plants by repeated trials of observation both in nature and in the classroom, by studying both specimens and pictures, and by acknowledging the variations and diversity of plants, and how they change. In such observation practices, the students are invited to turn towards a plant and position themselves to see it the best possible way. The students may have to move back and forth, looking at it from different angles to see it clearly, like one do in front of a picture in a gallery (cf. Merleau-Ponty). There might be several meaningful positions depending on both the observer and the observed, but it is through these movements the students gain skills and knowledge of living nature. Such experiences are educative, as ‘moving forces that opens to the growth of further experiences’, if you gain skills and knowledge you can use to further explore plants.

6.3 Acknowledging living nature

When observing living nature in an educational setting the conditions that create an experience are manifold and include both the phenomenon of living nature itself and various conditions for learning. Experiences are formed by interactions, for instance, between the student, a plant, and various materials in the classroom, as well as social interactions between the student and the teacher, and between the student and other students. According to Dewey, interaction is “the second chief principle for interpreting an experience in its educational function and force” (Dewey, 1938, p. 42), and “Continuity and interaction in their active union with each other provide the measure of the educative significance and value of an experience” (p. 44-45). Together, the principles of continuity and interaction form the longitudinal and lateral aspects of experience (p. 44). The longitudinal aspect of an experience is the timeline and history that any experience is part of, where the present experience is affected by earlier experiences, and at the same time modifies the quality of future experiences. The lateral aspect of an experience is the web of interactions that any experience is part of at any time. Dewey claims that you live in a series of situations that is formed by interaction, and that “an experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment.” (p. 43). The environment is defined as the conditions that interact with personal needs, desires, purposes, and capacities, to create a certain experience (p. 44).

This ongoing communication and interaction with the world is what Merleau-Ponty (2012) denotes as ‘the intentional arc’. Through experience the active body acquires skills that are stored as “dispositions to respond to the solicitations of situations in the world” (Dreyfus, 2002, p. 367). In other words, the ongoing interaction and communication with the environment results in skills that become part of who you are. From this standpoint, an educative experience enables you to acquire skills that lead to “finer and finer discriminations of situations paired with the appropriate response to each” (p. 367). The appropriate response to each situation would be to respond in such a way that whatever significant things that are brought along in the activity (cf. Heidegger) ‘present more of themselves’ (cf. Merleau-Ponty), either it is picking chanterelles, listening to birdsong, or identifying a clover-plant. Subsequently, when observing living nature, an educative experience means to acquire skills in response to living nature that give you a more nuanced familiarity with plants and animals. The phrase *in response to* is essential here and involves engaging in the activity of recognizing the phenomena in living nature by an open presence where you try to position yourself to see the phenomena the best possible way (cf. Merleau-Ponty).

To educators, the important part is to create conditions for educative experiences to happen, involving everything from social interactions to interactions with materials, plants, insects, and not least interactions between the educator and the learner. According to Ingold (2018), “the promise of education lies in the capacity to respond and be responded to: without such ‘response ability’, as we might call it, education would be impossible.” (p. 5). In *Anthropology and/as*

Education, Ingold comments and elaborates on Dewey's ideas on education. Here, Ingold argues against education as transmission, and for education as a practice of attention. According to Ingold, the first place to find education is in participatory practice in what he calls the correspondences of social life: "Knowledge grows along lines of correspondences: in communing, wherein they join; and in variation, wherein each comes into its own. Every way of knowing, then, is a distinct lifeline" (p. 17). To Ingold, correspondence means the longitudinal process of 'going along with', where being and things quite literally co-respond (answer to one another) over time. To be able to go along with and respond you must pay attention to things and beings and join and participate with your own 'lifeline' (p. 25-26). To the educator, it means to go along with the learners and give them opportunities to become attentive through exercises that stretch the learner's attention.

Education as a practice of attention means to *facilitate* for experiences that give the student a chance to make sense of the world by engaging in attentional practices that are intelligible to the student. To recognize living nature, the student needs to practice observation and gain skills and knowledge by repeated trials, and by exploring the variations, dynamics, and diversity of plants and animals *in* nature. According to Dewey, an educative experience is an experience that enhances the learner's sensitivity and responsiveness and enables the growth of further experience. An experience which is part of the student's understanding of being in the world might be educative in the deepest sense. By recognizing plants and animals, the students address themselves to the world (cf. Heidegger), and it is both an act of disclosing the phenomena in living nature, and understanding what being is. In correspondence with living beings in nature, where you pay attention and respond, knowledge grows along a distinct lifeline that comes into your own (cf. Ingold).

7 Research - studying lived experience

> Into the unknown; we do not know where we are going. We sail in a leaking boat, we know we are dying animals. We dream of Byzantium, we pour out the water, we sail together. We are argonauts, cosmonauts, adventurers, explorers. We are traveling. (Grue, 2018; my translation from Norwegian)[14]

7.1 Borrowing other people's experiences

Observing living nature is an aspect of human lived experience. In the book *Researching lived experience*, van Manen (2016b) describes phenomenological research as the study of lived experience or life-world of humans (p. 9). In this section, I explore what it means to phenomenologically investigate lived experience with observing living nature in an educational setting.

To research means literally "to study closely, search or examine with continued care". The term comes from French *rechercher* 'seek out, search closely', where -*cercher* comes from Latin *circare* 'go about, wander, traverse.[15] In other words, to research lived experiences with observing living nature means to seek out, or traverse and *re*-traverse such experiences with care. Although my experiences with observing living nature as for instance a biologist and biology teacher are manifold, researching the phenomenon of observing living nature requires that I collect experiences from others as well. According to van Manen (2016b):

> …the point of phenomenological research is to "borrow" other people's experiences and their reflections on their experiences in order to better be able to come to an understanding of the deeper meaning or significance of an aspect of human experience, in the context of the whole human experience (p. 62).

To be able to "borrow" other people's experiences, as a researcher, I need to collect and study people's own everyday experiences with a phenomenon, in my

[14] The original quote in Norwegian: «Inn i det ukjente; vi vet ikke hvor vi er på vei. Vi seiler i en båt som lekker, vi vet at vi er døende dyr. Vi drømmer om Bysants, vi øser det vi makter, vi seiler sammen. Vi er argonauter, kosmonauter, eventyrere, utforskere. Vi er på reise.»
[15] From Online Etymology Dictionary: https://www.etymonline.com/word/research

case observing living nature, and try to understand what these experiences are like for each person's life. In the context of primary school education, both teachers and students are possible participants.

However, to "borrow" other people's experiences is not straightforward. Studying lived experience means that I as researcher try to examine the lifeworld of other people, which means the world as they experience it. How you experience the world is usually not something you conceive of even yourself. Instead, such experiences are part of your being in the world, and as stated earlier, you normally make sense of things in activity and while coping with different tasks in your world, not reflecting on them (cf. Heidegger). It means that such experiences are not necessarily something you can verbally articulate. As a researcher, I must be aware of this. For instance, instead of starting to ask the participants to reflect on their experiences with observing living nature, it may be better to ask them to describe particular (and significant) situations related to the phenomenon. Even more straightforward, I can let them observe and describe a particular specimen or a picture of a living organism as part of an interview. This means that when borrowing other people's experiences as a researcher, there is a difference between gathering material of lived experience (like descriptions and anecdotes in logs or interviews) and gathering reflections on lived experience. The gathering of one or the other may be two different stages in a research-project (van Manen, 2016b).

According to van Manen (2016b), "phenomenology aims at gaining a deeper understanding of the nature or meaning of our everyday experiences"(p. 9). A phenomenological approach to research is a hermeneutical process where the researcher both describes the nature of human lived experience and interprets its meaning. A hermeneutical process can be described as an interpretive process. However, the role of interpretation is a source of discussion in phenomenological research. According to Merleau-Ponty (2012), phenomenology aims to describe, rather than explain or analyze experiences (p. xxi)[16]. Further, many researchers distinguish between descriptive and interpretive phenomenology, whereas others

[16] Merleau-Ponty (2012) elaborate on the statement in the preface of his book Phenomenology of perception and writes on p. xxii: "To return to the things themselves is to return to the world prior to knowledge, this world of which knowledge always speaks, and this world with regard to which every scientific determination is abstract, signitive and dependent, just like geography with regard to the landscape where we first learned what a forest, a meadow or a river is."

see different phenomenological approaches as a continuum where a specific phenomenological description may be more or less interpretive (Finlay, 2012). The question is what it means to describe and interpret a human lived experience, and how this describing and interpreting possibly differ from explaining or analyzing.

van Manen (2016b), by reference to Gadamer, makes a distinction between two senses of interpretation; interpretation as ‘pointing to meanings’ which could be part of phenomenological description, and interpretation as ‘pointing out the meaning’ of something (p. 26). To point out the meaning of something implies that the researcher imposes an external framework and explains, rather than tries to understand the meaning of a human lived experience. Likewise, to exemplify, there is a difference between explaining how a hammer works and understanding how a hammer works. To understand how a hammer works implies that you know how to use a hammer, and that the hammer ‘belongs’ to activities that are meaningful to you as part of your being in the world (cf. Heidegger). Explaining how a hammer works, on the other hand, by imposing an external framework like Newton’s laws of motion, implies that you see the hammer as detached from you and make causal explanations about how the different parts of the hammer work, from the outside. It further implies that you don’t necessarily have to know how to use a hammer to be able to explain how a hammer works. Thus, interpretation of human lived experience as ‘pointing to meanings’, means to seek out the essential qualities with such experiences from the inside (from the people who live them) and what the experiences mean in the context of the whole human experience. An interpretation of human lived experience as ‘pointing out the meaning’, on the other hand, means to impose an external framework to analyze and explain an experience from the outside.

Phenomenologically investigating other people’s experiences with observing living nature may be both a descriptive (phenomenological) process describing the nature of the phenomenon, and an interpretive (hermeneutical) expression of the meaning of the lived experience (van Manen, 2016b, p. 38). To be able to point to meanings, I need to recognize the lifeworld of the participants in their actual context and gather what is called ‘thick descriptions’ (e.g. Creswell & Poth, 2018, pp. 245-246) of lived experience. Recognizing the lifeworld of the participants involves that I demonstrate ‘response-ability’ by way of paying attention to things and beings and ‘co-respond’ by joining and participating in their lifeworld (cf. Ingold). This way to research lived experience may also be seen as a practice of paying attention by both being sensitive and responsive to other people and their lifeworld.

7.2 Being a close observer

As a researcher, I may also seek out experiences with the phenomenon by close observation of the participants while they observe living nature in familiar settings. In close observation, you try to break through the distance that is often created by methods of observation, by participating in the lifeworld of people, but still retaining the ability to step back and reflect on the meaning of those situations (van Manen, 2016b, pp. 68, 69).

As previously described, observation is an attentional turning towards the world and often a movement of going back and forth and finding a position where the observed ‘present more of itself’. When you observe, you position yourself in the world to explore a phenomenon in ways that are intelligible to you. Such observation always takes place within a particular body and within a specific context (cf. Merleau-Ponty). In this case it is my particular body, and the context is that of researching experiences with observing living nature in an educational setting. My prior experiences have made me deeply interested in the question of what the meaning of observing living nature in (science) education is. This question has a living significance to me. According to van Manen (2016b), “a phenomenological question must not only be made clear, understood, but also “lived” by the researcher” (p. 44). My own lived experience enables me to question and investigate the phenomenon from the inside because the question how to recognize living nature has arisen from the center of my being as both a biologist, a teacher, and a teacher educator. My familiarity with the phenomenon hopefully makes it possible for me to observe in such ways that the phenomenon ‘presents more of itself’ (cf. Merleau-Ponty) and becomes clearer, and at the same time more nuanced.

On the other hand, this interest [17] and the abiding concern with the phenomenon may predispose me to interpret the nature and meaning of the phenomenon. In phenomenology, the term ‘bracketing’ is used to describe the process of placing one’s knowledge and pre-understanding aside in order to observe a phenomenon. ‘Bracketing’as the preliminary step in phenomenological research, is described in terms of ‘reduction’ or ‘epoché’ (from Greek: ‘a suspension of judgement’). This process is central to practicing phenomenology (van Manen, 2016a, p. 222). However, what it means to ‘bracket’ or ‘suspend’ one’s own knowledge and pre-understandings has been understood in various ways, and it has been highly disputed how and at what stage it should occur in the research-process (e.g. Dowling, 2007). According to van Manen (2016b), instead of trying to ignore what we already ‘know’, “it is better to make explicit our understandings, beliefs, biases, assumptions, presuppositions, and theories” (p. 47), not in order to forget then, but to keep them at bay[18].

‘Bracketing’ or ‘epoché’ may be understood as an attitude rather than a method or a stage in the research process and can be described by the four aspects of wonder, openness, concreteness and approach (van Manen, 2016a, pp. 222-228).To me as a researcher, either in close observation, or in other stages of the research process, the attitude of ’suspending judgement’ means to have a disposition of wonder and openness to the phenomenon of observing living nature and how the phenomenon is experienced by the participants. The attitude involves looking for the extraordinary in the ordinary, questioning assumptions and pre-understandings throughout the research process, favor concrete descriptions of experience over abstractions, and seek approaches that fit the phenomenon under study most appropriately.

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[17]From Latin, *inter* "between" + *esse* "to be", to be in the midst of something. From Online Etymology Dictionary: https://www.etymonline.com/word/interest

[18] The full statement is: “It is better to make explicit our understandings, beliefs, biases, assumptions, presuppositions, and theories. We try to come to terms with our assumptions, not in order to forget them again, but rather to hold them deliberately at bay and even to turn this knowledge against itself, as it were, thereby exposing its shallow or concealing character” (van Manen, 2016b, p. 47).

7.3 Writing phenomenologically

The challenge to describe how a phenomenon appears to someone, is that "what 'appears' is not at all something apparent or clear-given" (van Manen, 2016a, p. 61). Phenomenological descriptions and interpretations may be an affirmation of someone's experiences, but at the same time they may challenge what is taken-for-granted. According to Henriksson (2012), phenomenology "holds a promise of both proximity and distance, the familiar and the alien, the known and the not yet known" (p. 3). This implies that the descriptions of the phenomenon of observing living nature in an educational context should be close to practice and experience, and at the same time, try to see something new and describe something not yet described.

When I as a researcher ask; what is the nature and meaning of observing living nature in science education, the aim is to describe the essence of lived experiences with this phenomenon. Essence has at least two meanings in English: first, "intrinsic nature or indispensable quality" of something, and second, an "extract or concentrate" obtained from a plant or other matter[19]. To describe the essence of lived experience is to search for the intrinsic nature of the experience and describe the qualities that are indispensable to this experience. Such a description may be an extract or concentrate, however, the aim is to gain insightful descriptions of experience that also 'point to the meaning' (cf. van Manen) of these experiences.

One way to make such descriptions is to conduct what is called a thematic analysis (cf. van Manen) and formulate themes. As a researcher I gather material that is either material of lived experience with observing living nature, like anecdotes in logs and interviews, or notes from my own observations, or material that consist of reflections on lived experience with the phenomenon. To describe the essence of these experiences and examples in writing, I may seek to find themes in the material that open up and deepen both the nature and meaning of these experiences. According to van Manen (2016b), "phenomenological themes are like the knots in the webs of our experiences, around which certain lived experiences are spun and thus lived through as meaningful wholes.", and the

[19] From Google's English dictionary provided by Oxford Languages: https://languages.oup.com/google-dictionary-en/

themes “have phenomenological power when they allow us to proceed with phenomenological descriptions (p. 90). Thus, themes can be seen as ‘knots’ around which the phenomenological description is facilitated. A theme is an experience of focus that describes an aspect of the structure of lived experience.

The overall aim of researching lived experience phenomenologically is to come to an understanding of the significance of aspects of human experience, in my case the experience of observing living nature in the context of teaching and learning. The phenomenon of ‘observing living nature’ has a living significance to me, as a biologist, biology teacher, aunt, mother, and human, which makes it possible for me to question and investigate the phenomenon as lived experience (from the inside). In the process I also borrow other people’s lived experiences that expand and become part of my own lived experience with the phenomenon. I engage in the activity of researching by seeking out multiple experiences with the phenomenon, and in the process the phenomenon possibly becomes clearer and more nuanced. Only by engaging in the world myself I can understand my being as a researcher or a biology teacher and make the world intelligible. To describe the essences of experiences with observing living nature in an educational setting in a text is to reflect upon and respond to other people’s experiences, while at the same time to reflect on the meanings of these experiences in the context of the whole human being. To write phenomenologically thus means to communicate with others in a process of correspondence (cf. Ingold), and as part of my own lived experience. In the last chapter, I will come back to my own experiences in a methodological discussion.

PART III: Research design and methods

In my PhD project, I applied a phenomenological approach as described in Part II. In this part, I describe more specifically the research design and methodology I have used to answer the four research questions posed in Chapter 3:

1. How might cases from the history of science be designed to strengthen teachers' and students' observational practices and knowledge about living nature?
2. How do teachers experience the practice of observing living nature in the context of teaching and learning science in primary school?
3. How do 5th grade students experience different modes of observing living nature demonstrated through four cases from the history of science?
4. What are the potentials and constraints with teaching and learning observational practices in primary school?

My PhD-project has three phases: Phase 1 prepares four teaching cases from the history of science, Phase 2 implements the four cases in a course for primary school tecahers, and Phase 3 explores how the teachers implement the cases in school (Figure 1). Phases two and three are both related to the same case study (see Chapter 9).

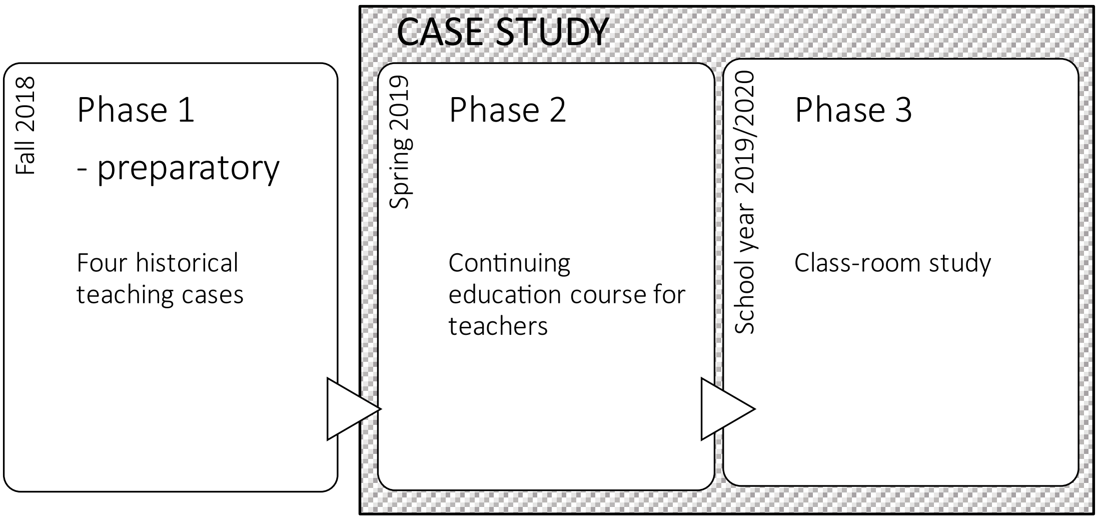


Figure 1: Research design

The first phase attempts to answer research question 1, and is a preparatory phase for the next two phases. In phases two and three I conducted a qualitative case study to answer research questions 2 and 3. The unit of inquiry in the case study is a case with five teachers and their students in fifth grade in primary school. Research question 4 will be answered in an overall discussion including all three phases, in Part V of this thesis..

In Chapter 8, I describe the approach and selection criteria for preparing the teaching cases in Phase 1, and present the historical sources and the method of analysis I have used. In Chapter 9, I describe the case study with teachers and students in phases two and three. I present the selection criteria, participants, context, and dicuss reasons for using a case study as the research method. In Chapter 10, I describe the implementation of the teaching cases in the continuing education course for teachers in phase two, and the implementaion of the same teaching cases in the classroom with students in phase three. I present the methods for collecting material and how I conducted the analysis in both phases two and three.

8 Preparing historical teaching cases

In the first phase of my investigations (Figure 2), the research question is:

> How might cases from the history of science be designed to strengthen teachers' and students' observational practices and knowledge about living nature?

I will describe my approach and the selection criteria used to select the four teaching cases from the history of science. I present the historical sources I have used and explain how I have analyzed these sources in three steps to formulate foundational questions, extract types of observational practices, and discuss what has been perceived as relevant in these modes of observation historically. At last, I will describe how I have designed the four teaching cases based on my analysis of the historical sources.

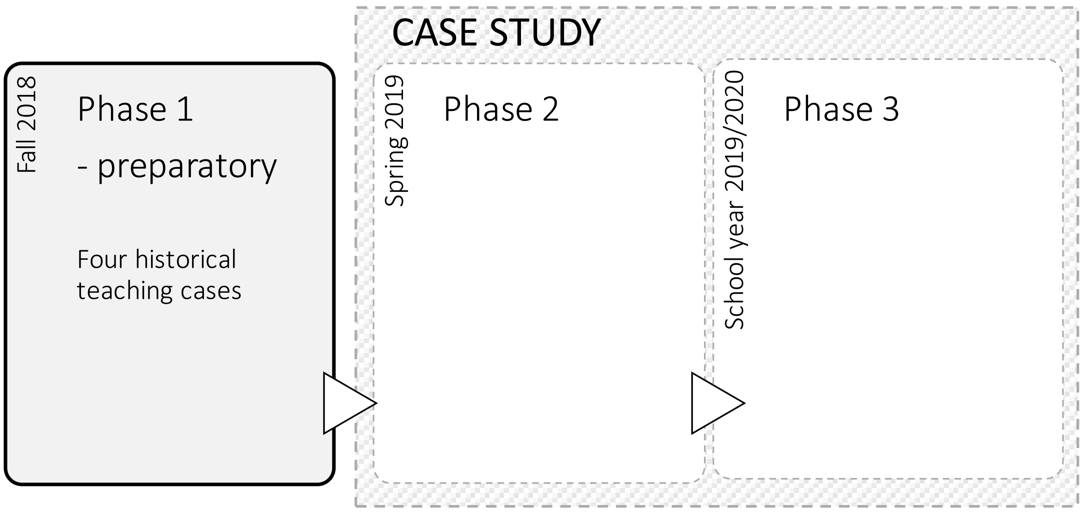


Figure 2: Phase 1 is a preparatory phase for the case study in Phase 2 and Phase 3.

8.1 Approach and selection criteria

In phase 1, the aim was to develop historical teaching cases that demonstrate complementary observational practices in the exploration of living nature. The three phases in this study were planned together and the historical teaching cases were selected and prepared to be used, first, in the continuing education course for the teachers in Phase 2, and second, as a base for teaching the students in fifth grade in Phase 3.

The history of science is extensive and diverse, and a selection of a few cases can never tell the full history of observational practices in biology. The purpose was to select historical cases that could be used as examples in teaching to portray contrasting and complementary observational practices when exploring living nature, and at the same time show some aspects of science as a set of dynamic, varied, and historical practices (cf. Chapter 2, section four).

Any history of past events assumes some selection of actors, ideas, and practices. According to Barseghyan (2022), “an important historiographic question is not whether to be selective but instead how to be selective responsibly” (p. 61). He writes that “the fault of a poorly written historical narrative lies not in the fact of selection per se but rather in the specific way the selection is made” (p. 62). Explicitly stated selection criteria will clarify which past events are relevant to the project. Three of the most practiced selection criteria when studying the history of science are “selection by actor intentionality”, “selection by later effect”, and “selection by problem” (p. 63). Based on these general selection criteria, I have used the three more specified selection criteria to select the historical teaching cases in my investigations:

1) The central actor in the case intentionally engaged in observing living nature.
2) The central actor in the case demonstrates skilled observational practices that contributed to later practice.
3) The central actor in the case demonstrates a practice that is an attempt to answer a fundamental question regarding the phenomenon of observing living nature.

I have applied several selection criteria that are complementary to each other, having several selection criteria could be called a pluralist approach (Barseghyan, 2022; Smith, 2009). I decided to select one case from each of the four different time periods: antiquity, renaissance, enlightenment, and beginning of the modern period (see Table 1). These time periods represent major shifts in the history of science, where the intentions and practices of investigating nature changed. I expected these differences to be mirrored in the ways in which natural philosophers practiced observation of living nature in the respective time periods.

Thus, I looked for a central actor of each time period that fulfilled the three selection criteria above.

8.2 A discussion of the selection criteria

The selection of cases made in historical studies, is related to the highly discussed question in the historiography (the study of the writing of history) of science, namely the role and meaning of presentism (e.g. Barseghyan, 2022; Colla, 2021; Jardine, 2003; Loison, 2016). Presentism refers to “a tendency to view the past from the perspective of the present” (Colla, 2021, p. 124). In a broader context, presentism refers to how historians connect past and present in ways that may have both methodological, epistemological, and ontological significance. The maxim in historiography has been to avoid presentism, however, the question may rather be how to use presentism (Barseghyan, 2022; Jardine, 2003; Loison, 2016). Our present understanding can help us better understand the past, as well as it can lead us to misinterpret it. Barseghyan (2022) introduces the concept of selective presentism and discusses how the three above mentioned selection criteria interact with different forms of presentism. I find this discussion relevant to the selection criteria in my project and will give a brief overview of the discussion related to each of the selection criteria.

1. *The central actor in the case intentionally engages in observing living nature.*

Selection of historical cases by actor intentionality depends on whether a case falls under the given practice without distorting or misrepresenting the activity the actors in the past were intentionally engaged in (Barseghyan, 2022). In the history of science, this will to a certain degree depend on how we understand science. Starting from a narrow and present-day notion of science would for instance not include cases from the antiquity, or the renaissance, in the history of science, because actors from these time periods did not (and could not) intend to do science in the way we understand science today. However, if we understand science in broader terms as, for instance, “the interaction of humans with their natural environment and their aspirations to understand it” (Smith, 2009, p. 346), this includes the selection of older cases as long as a chosen case represents the actor’s intentional activity.

In my selection process, I have assumed a broad understanding of science that includes cases from the Antiquity and the Renaissance (cf. Smith, 2009). The central actors in the four selected cases were all engaged in the practice of observing living nature and aspired to understand it.

2. *The central actor demonstrates skilled observational practices that contributed to later practice.*

Selection of historical cases by later effect depend on whether a historical event contributed to bringing out some essential aspects of the given practice (Barseghyan, 2022), for instance, some aspects that had subsequent effects on scientific practices. To trace events of the past that proved to be important is fundamental to any historian and inherent in most historical studies (Loison, 2016). However, this is not an easy task and it is important not to "misconstrue what historical actors were doing by assuming that they were trying to get to where we are today" (Barseghyan, 2022, p. 65).

Knowing what we know today, the central actors in each of the four selected cases in my study without doubt have had a subsequent effect on scientific practices. However, to avoid misconstruing stories by a present-day perspective, I have tried to describe the central actors' activity without assuming that the actors aimed at answers we have today. I have used primary sources and the actors' own way of asking questions as a starting point to clarify both the intention with their explorations and how the question is related to a certain mode of observation.

3. *The demonstrated practice in the case is an attempt to answer a fundamental question regarding the phenomenon of observing living nature.*

A third approach to selecting historical cases is selection by problem, where a question is the starting point of the historical investigations (Barseghyan, 2022). The selection of cases will depend on whether a certain practice or activity is an attempted solution to the question at hand. Jardine (2003) argues that attention to questions is crucial in the historiography of sciences. Questions provide the agendas of the sciences and are influenced by the material conditions and social practices at a certain place and time. Jardine further argues, by referring to a previous work (Jardine, 2000), that “attention to changing problems in the sciences, to the ways in which questions become real and cease to be real, opens the way to a new kind of Big Picture of the history of disciplines” (Jardine, 2003, p. 134). It means that selecting cases that demonstrate how questions become real and cease to be real, according to different material conditions and practices, may have the potential to illustrate essential aspects of scientific disciplines. Jardine (2000) argues: “Reality of questions in a community has been explicated in terms of communal dispositions to acknowledge the relevance of evidential consideration to those questions” (p. 77). Thus, the changing reality of questions in the history of science are explained by different perceptions of relevance, where the immediate determinants of such perceptions are presuppositions and methodological commitments (Jardine, 2000, pp. 78 -79).

In my selection process, I looked for historical cases that were attempted solutions to the overall question of how to explore living nature, and at the same time, posed different fundamental questions to make these explorations.

8.3 The four selected cases

In the end, I selected four cases represented by the following five central actors: Aristotle, Maria Sibylla Merian, Carl von Linné, Alfred Russell Wallace and Charles Darwin (Table 1). All of them intentionally engaged in the practice of observing living nature, they demonstrated skilled observational practices that contributed to later practice, and they attempted to answer a fundamental question regarding the phenomenon of observing living nature. In the following, I will argue in which ways these actors are part of a scientific practice of observing living nature representing the time-period they were living in.

Aristotle lived from 384 – 322 BC and was a significant contributor to the development of natural history in the classical antiquity. In this period, inspired by ancient works from Egypt and Mesopotamia, the natural philosophers investigated nature and attempted to find explanations in the physical world based on natural causes (e.g. Lindberg, 2010). Aristotle has been called the first biologist and a large amount of his writing was dedicated to investigations of the living parts of nature. The case of Aristotle demonstrates an empirical approach to investigating nature, as opposed to the more rationalistic approach by his teacher Plato, based on comparative observations of living organisms.

Table 1: Four historical cases and their central actor

Case	Time-periods[20]	Central actor
I.	Classical antiquity (About 8^{th} century BC to 5^{th} century AD)	Aristotle (384 – 322 BC)
II.	Renaissance (About 14^{th} to 17^{th} century)	Maria Sibylla Merian (1647 – 1717)
III.	Enlightenment (About 17^{th} to 18^{th} century)	Carl von Linné (1707 -1778)
IV.	Late modern period (About 18^{th} century to present)	Charles Darwin (1809 -1882) and Alfred Russell Wallace (1823 -1913)

Maria Sibylla Merian lived from 1647-1717 and belonged to what Ogilvie (2006) has called “the science of describing” in renaissance Europe. In this period, inspired by the classical texts from the antiquity, the naturalists started to observe and record plants and animals as they saw them in nature. The printing press was introduced, and books of plants and animals became available to a much larger audience than before. The naturalists also created new techniques of observing and recording plants, like botanical gardens and herbariums, which made the plants more accessible to study, but at the same time removed the plants from their natural context (Ogilvie, 2006). In the margins of this community of naturalists, Merian observed and recorded the life cycle of many species of butterflies for the first time and in a new way. She has been called the first ecologist (Etheridge, 2011). Merian published two major works with detailed illustrations of the life cycle of both local and foreign butterflies. The illustrations were made with copper engraving, printed, and some of them were then hand colored. Although, as a woman, she was not allowed to be formally educated as a naturalist or a painter, but she was self-educated as both. The case of Merian demonstrates, both a science and an art of describing living organism as we see them in nature, based on an ecological approach (Etheridge, 2011).

Carl von Linné lived from 1707-1778 and was at the center of a community of naturalists in Europe during the period of enlightenment. In this period, there was

[20] The indicated time-periods can be defined in several ways and the labels are not unambiguous. Here, I have used definitions from the Encyclopedia Britannica: https://www.britannica.com/event/.

a general emphasis on reason in society and on the utility value of science. Within the community of naturalists there was a discussion on which criteria to use when classifying especially plants, and whether there existed such a thing as a natural system (e.g. Sloan, 1972). Many different systems of plant classification were in use at the same time, and there was a rapidly growing documentation of plants and animals from all over the world, which resulted in an information overload (Müller-Wille & Charmantier, 2012). Linné investigated medicinal and economic benefits of plants and animals and expected to find order in nature. He managed to overcome the information overload and make a dynamic system that could be expanded over time. The case of Linné demonstrates how to systematize and name large numbers of plants and animals based on analytical observations.

Charles Darwin lived from 1809 -1882, and Alfred Russell Wallace lived from 1823 -1913. They both contributed to a whole new way of observing and explaining the diversity of living organisms. In this period, which was the start of modern biology, the naturalists struggled to unify observations of living organisms around the world and to explain the vast diversity of species. The cell theory was first formulated by Theodor Schwann and Matthias Jakob Schleiden in 1839, and further developed by Rudolf Virchow in 1858. The cell theory stated that all living organisms are composed of one or more cells, and that the cell is the basic unit of structure and organization in living organisms. Virchow (1860) added that all cells arise from pre-existing cells. The theory unified the studies of living organisms and implied a common origin. Studies in geology in the same period had demonstrated that life on earth had changed through time (Lyell, 1835). The question that arose was: Where do all the species come from, and how do they change? Wallace and Darwin had different social and educational backgrounds. However, as young men they both traveled around the world to document and collect specimens of exotic plants and animals, and they both occupied themselves with the questions about the origin and development of life on earth. Independently of each other, they both formulated a theory that could explain the origin of species, based on a synthesis of many different kinds of observations (Darwin & Wallace, 1858).

As I hope to have demonstrated, these four cases and their central actor(s) represent the four selected time periods by the way in which each of the actors explored living nature. The cases show how the perception of what was relevant to observe within the practice of observing living nature changed according to the historical context. Although I argue that these actors represent their respective time-periods, each of them also challenged and introduced new aspects to the practice of observing living nature in their time.

All the four cases meet the criteria described earlier. However, this is not an exhaustive selection of cases. There could have been more cases, and there could have been other cases that would have met the same selection criteria. Still, this selection of cases seems to demonstrate essential and complementary features of the practice of observing living nature that could be useful in teaching and that could be used as a base to answer the research questions in my thesis.

8.4 Use of historical sources

In addition to selecting which historical *cases* to investigate, the process of studying past events necessarily involves the selection of which historical *sources* to use. Primary documents include the original and contemporary source material on an event, and secondary documents are sources about the event written subsequent in time (Thies, 2002, p. 356). Primary sources are characterized by their content and could be, for instance, original documents (also excerpts and translations), creative works, and relics or artifacts (Harvard, 2022). The historical sources I use as a base for investigating the historical cases are primary documents by Aristotle, Merian, Linné, Wallace and Darwin. In addition, I use some secondary documents by historians of the sciences (Table 2). In the case of Merian, I use primary sources mainly in form of the pictures she made, using digital resources online [21], rather than texts.

I am limited to studying the primary sources that are available to me in English or Norwegian, either in printed books or online. In addition, each of the actors in the four selected cases has produced enough material for a lifetime of investigations, which make a further selection necessary. According to Thies (2002), it is important to acknowledge that in the process of selecting which historical sources to investigate, the researcher selects sources that are readily

[21] For instance, online resources from The British Museum: https://www.britishmuseum.org/collection/animals/maria-sibylla-merian-pioneering-artist-flora-and-fauna

available to them. The sources may have been preserved by some person or organization for a certain purpose, or they may have survived through time quite accidently. In some cases, the access to primary sources may be restricted. Either way, the researcher should be aware of dealing with a selection of primary sources to begin with and take that selectivity into account when making inferences (p. 357). Thus, my analysis as described in the next section is limited by the primary sources that were available to me and that I found meaningful to investigate within the context of this project (listed in Table 2).

Table 2: A list of primary and secondary sources used in each of the four teaching cases.

Case	Primary sources	Secondary sources
I	• On the parts of animals (Aristotle, 1990b) • History of animals (Aristotle, 1990a)	• The lagoon: how Aristotle invented science (Leroi, 2014) • The Beginnings of Western Science. The European Scientific Tradition in Philosophical, Religious, and Institutional Context, Prehistory to A.D. 1450 (Lindberg, 2010)
II	• Der Raupen wunderbare Verwandelung, und sonderbare Blumen-nahrung (Merian, 1679)	• Maria Sibylla Merian: The first ecologist? (Etheridge, 2011) • A Butterfly Journey. Maria Sibylla Merian. Artist and Scientist (Friedewald, 2015) • The science of describing : natural history in Renaissance Europe (Ogilvie, 2006) • The Girl Who Drew Butterflies: How Maria Merian's Art Changed Science (Sidman, 2018)
III	• Systema Naturae 1735: Facsimile of the first edition with an introduction and english translation of the "Observationes" (Engel-Ledeboer & Engel, 1964) • The Families of Plants, with Their Natural Characters (Linné, 1787)	• In the field: exploring nature with Carolus Linnaeus (Hodacs, 2010) • Gardens of paradise (Müller-Wille, 2001) • Linnaeus' herbarium cabinet: a piece of furniture and its function (Muller-Wille, 2006) • Natural history and information overload: The case of Linnaeus. (Müller-Wille & Charmantier, 2012)
IV	• On the Tendency of Species to form Varieties (Darwin & Wallace, 1858) • On the origin of species by means of natural selection (Darwin, 1859) • On the law which has regulated the introduction of new species (Wallace, 1855) • The Malay Archipelago (Wallace, 1869)	• The life of Charles Darwin (Darwin, 1995)

However, as stated earlier, it is not possible to do research without being selective, the point is rather to be explicit about the choices made. Since the main objective of this project is to explore the phenomenon of observing living nature, the selection of historical sources is performed on that background. The selected sources, both the primary and secondary documents, all address the central phenomenon and the overall question on how to explore living nature.

8.5 Method of analysis

I have analyzed the historical sources (Table 2) in three steps to define the fundamental question in each case, to extract types of observational practices, and to discuss what was historically perceived as relevant in these observations of living nature.

According to Jardine (2000), the changing questions in the history of science, demonstrates different perceptions of relevance in the inquiries into nature. To describe the changing norms for what is considered good research, Jardine (2000) uses the term "changes in scenes of inquiry" (p. 77). According to Elwick (2007), others have called the same phenomenon "styles of reasoning" (e.g. Bueno, 2012; Hacking, 2012), "thought-styles" (Fleck, 1979), "themata" (Holton, 1996), or "ways of knowing"(Pickstone, 1993). The main point in common is:

> Historically, a style made certain kinds of inquiries possible, and yet by helping a researcher commit to solving certain problems, it also restricted and excluded alternative inquiries. This partly stemmed from how evidence was used in different styles – someone using one style of reasoning presupposed certain kinds of evidence to be more relevant than other kinds (Elwick, 2007, p. 36).

Different "styles of reasoning" or "changes in scenes of inquiry" in science, relate to different perceptions of relevance in the inquiries into nature, or more specifically in my project, to what is perceived as being relevant observations when exploring living nature. Jardine (2000) specifies that there is far more to a style of inquiry than forms of reasoning, or organization of discourse, and states that a "style of inquiry is to be identified with the totality of practices involved" (p. 245) in the resolution of questions. Emphasizing the changing questions in the practices involved in the inquiry process, “shifts the analytic attention from processes of validation and justification to processes and contexts of knowledge generation” (Schickore, 2020, p. 494).

Thus, my analysis, through its emphasize on the questions in each of the four historical cases, focuses on the practices and processes of knowledge generation, and the contexts of these processes. The aim is to describe processes of knowledge generation as different observational practices involved in exploring living nature. The three steps in my analysis of the historical sources are:

1) To define a fundamental question asked in these past works, one for each case. The question conveys the intentional objective of the described observational practice.
2) To extract a typology of observational practices based both on the fundamental questions in each case and the practices applied by the central actor in answering the question.
3) To discuss and compare the changing questions to find what determines perceptions of relevance in each case.

Based on the four selected cases from four different time-periods, I find fundamental questions in each case and extract a typology of observational practices. This means that I interpret the historical sources. In historical research the predominant stance is that an interpretation of historical sources tries to understand historical actors and sources in their own context, and the original author’s intention in producing the source (Kipping et al., 2013, pp. 320 -321). Emphasizing the questions asked by the central actors in each case, may help me to clarify such intentions. According to Jardine (2000), by reference to Gadamer’s theory of interpretation:

> …he [Gadamer] insists that we recognize that we can understand a text only when we have understood the question to which it is an answer and that we beware of uncritical and doctrinaire assimilation of past works, allowing ourselves rather to listen and respond to the questions that they address to us (p. 69).

Gadamer’s theory of interpretation rests on a phenomenological approach and the process of interpretation is a question of attitude rather than a method. Gadamer’s theses of “enabling power of prejudice” and “fusions of horizons” are crucial in the process (Jardine, 2000, p. 68). The first thesis means that I as an interpreter have a horizon of understanding that are considered as conditions, rather than obstacles, to the possibility of interpreting past works (cf. the discussion of presentism in the previous section). The second thesis means that an understanding of past works involves a response to and an appropriation of the past work, that may change my own horizon of understanding.

Thus, building on these perspectives in the interpretation of the selected historical sources, I use my experiences as a biologist, teacher, and teacher educator, to define what I perceive as the fundamental questions asked in these past works. These questions in turn, point towards different intentions with the explorations of living nature that help me to extract different types of observational practices. As the last step of the analysis, I respond to these past works and discuss how the processes and contexts of knowledge generation may influence what is perceived as being relevant observations when exploring living nature.

The results of my analysis are presented in Part IV, as four cases with four fundamental questions and a typology of observational practices, and a discussion of what has been perceived as relevant to observe in the exploration of living nature in each of the four cases.

9 Research approach to the case study

In this chapter I will describe the research approach I used for the case study with teachers and students in phases two and three (Figure 3). I will start by describing what I mean by a qualitative research approach and go on to discuss the design and selection criteria in this case study. Then I will give a description of the context and the participants and discuss why I use a case study as the research method in phases two and three.

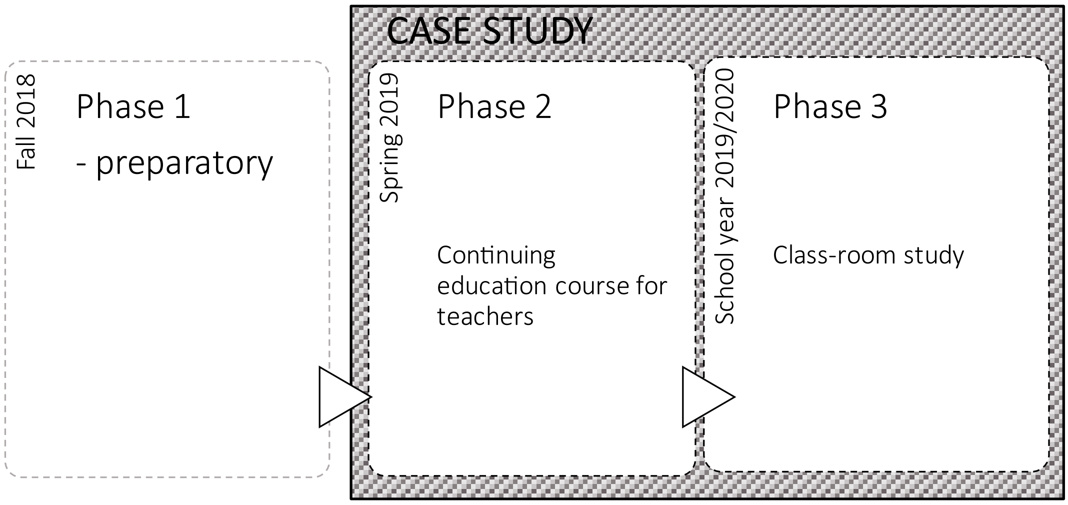


Figure 3: Phases 2 and 3 constitute the case study with teachers and students.

9.1 A qualitative case study

The qualitative research approach in this study implies that I describe qualities of the practice of observing living nature in the context of teaching and learning in primary school. According to Denzin and Lincoln (2011) "Qualitative research is a situated activity that locates the observer in the world." (p. 43). This means that in a qualitative exploration there will be a focus on the specific (time, place, personal stories) rather than on the general. The context gives meaning to the investigated phenomenon, and my subjectivity as a researcher is part of this context. Objectivity is replaced by acquiring several different perspectives in the form of a triangulation, or what Denzin and Lincoln (2011, p. 243-244) call a crystallization. It is a metaphor that indicates that reality is complex and that phenomena can change when we study them. In a crystallization process, the crystal grows and changes, reflecting images on the outside and bending the light on the inside, and it can look different from different angles. In my case study, different angles regarding the phenomenon of observing living nature, are acquired by including the voices of five central historical persons in the classroom, and from in-depth interviews with five teachers and six students in primary school. In addition, my lived experience as a biology teacher, teacher-educator, biologist, and researcher will be part of the descriptions and/or analysis.

As a researcher I use what are called thick descriptions (e.g. Creswell & Poth, 2018, pp. 245-246). Detailed and holistic descriptions will enable readers to consider whether the findings are valid in other similar situations as in a naturalistic generalization (Stake, 1995). In this study, the qualitative research approach is based on a phenomenological understanding of knowledge (as elaborated in Part II). This means describing the phenomena as the teachers and students experience them. According to Kvale and Brinkmann (2015), a phenomenological approach is about "understanding social phenomena from the actors' own perspectives and describing the world they perceive" (p. 45).

Case study research is a mode of inquiry where in which the case studies are the research method and the case(s) is(are) the unit(s) of inquiry (Yin, 2018). A case study examines one or a few special cases and thus enables an in-depth analysis of the phenomenon in the real context through various methods. Yin (2003) writes "In brief, the case study method allows investigators to retain the holistic and meaningful characteristics of real-life events" (p. 2).

In my investigations, I conduct a case study with a local primary school and the teachers and students in fifth grade at this school. The main topic of this case study is the experiences of observing living nature in a real-life context of teaching and learning. According to (Yin, 2018) a case study can have six different sources of data each with different strengths and weaknesses: documents, archives/ collections, interviews, direct observation, participatory observation, and physical objects (p. 114). In general, a case study is strengthened by using multiple sources of data. In my study I use teachers' reflection logs (written documents), teachers' answers to a course evaluation survey (written documents), teachers' group conversation (audio- recorded), interviews with teachers and students (audio-recorded and transcribed), notes and photos from participatory observation in the classroom and students' work (answers and drawings in booklet and journal). I will elaborate on these later when I describe the collection and analysis of material in phase two and three in Chapter 10.

Here, it is necessary to clarify the differences between a case study for doing research and cases designed for teaching (Yin, 2018, p. 19). My PhD -project includes both types. I have investigated four historical cases for teaching, and subsequently used these teaching cases as the starting point for the overall case study including teachers and their students in a primary school. The important point here is that the teaching cases must not be confused with the case study I describe as the overall research method in phases two and three of my PhD -project. First, the approach and intentions of preparing the historical teaching cases are different from a research-oriented case study. Second, according to Yin (2018) a case study for doing research focuses on contemporary events (p. 10). In the historical teaching cases, the gathered data consist of primary and secondary sources of historical documents, and for obvious reasons, cannot include direct observations or interviews with the persons involved.

Thus, in my study, the four historical teaching cases provide the starting point for performing a case study of observing living nature in a contemporary and real-life context of teaching and learning. I will go on to describe the overall case study I used as a methodology for doing research in phases 2 and 3.

9.2 Why use a case study as the research method?

My main research question relating to the case study is comprised of the research question two and three which both start with *how* (see p. 59). According to (Yin, 2018, p. 9), a case study is appropriate to answer how- and why questions, compared to other studies as experiments, when the study has little or no control over behavioral events and focuses on contemporary events. My study aims to investigate lived experiences and contemporary real-life events of teaching and learning, and thus, cannot control behavioral events as in an experiment.

It could be discussed whether the implementation of the four teaching cases rather makes the study an action research project. According to Sáez Bondía and Cortés Gracia (2021): “Action research aims to improve educational practice by means of reflective cycles (...). A case study, described as an umbrella term, focuses on understanding classroom situations in real contexts” (p. 850). I my study, I did not have a clear aim to directly improve the educational practices at the school. Rather, I wanted to implement the historical cases and describe both the teachers' and students' experiences with these cases and the phenomenon of observing living nature in a context of teaching and learning science. The implemented cases served as a starting point for the teachers and students to get different experiences with various observational practices. During the project I had several, informal and formal, conversations with the teachers, but not as systematic reflective cycles, as would be the case in an action research project.

Yin (2018) calls case study research a linear, but iterative process, with several steps required to plan, design, prepare, collect, analyze, and share (p. xxxi). As I understand it, case study research may be a process of going back and forth between the steps. However, the case study research process is still different from the cycles in an action research process. Action research generally has continuing reflective cycles to improve a practice, while case study research ends with a description of the qualities of the investigated phenomenon at the time. Although a case study may conclude with some recommendations to improve a practice, the actual improvement of a practice is not the aim of the case study. However, in a larger context of research, my study could be seen as part of a long term action research project according to Sáez Bondía and Cortés Gracia (2021), if, for instance, I would follow up this study with another case study based on the experiences with the aim of improving the practice of teaching science.

9.3 Selection criteria and design of the case study

My objective is to study experiences with observing living nature in an everyday context of teaching and learning, and then, to describe the qualities of these experiences. The selected case should be appropriate for achieving this overall objective and enable me to answer the research questions.

I have selected a case consisting of a team of five teachers and their 69 students in fifth grade in a public primary school in Norway. Some necessary prerequisites for choosing this case were that the headmaster was positive and enthusiastic about the project, and that the teachers were willing to participate in the study. The team of teachers were given the opportunity to attend the continuing education course as part of the school's developmental work and were willing to attempt the implementation of the historical teaching-cases with their students. In addition, there was a convenient aspect of the school being close to the university where I work. All this gave me the opportunity to investigate the topic and use the investigations to answer my research questions.

The case study has a single-case design with embedded units of analysis (Figure 4). Instances of embedded units of analysis may be individuals within the case, and a single-case design may include several embedded units of analysis as long as these units are within the original case (Yin, 2018). In my case study with teachers and students, the main embedded units of analysis are five teachers and six selected students. The five teachers make up the whole team of teachers within the case, while the six students are a selection of the 69 students within the case.

The main sources of analysis were in-depth interviews with the five teachers at the end of phases two and three, and three shorter interviews with the six selected students during phase three. However, in a case study, it is important that the focus does not remain with the subunits, but returns to the overall case as the main unit of the study (Yin, 2018, pp. 52-53). This means that, although focusing on the five teachers and six students as units of analysis, the main objective of my case study was still to study experiences with observing living nature at the level of the whole case.

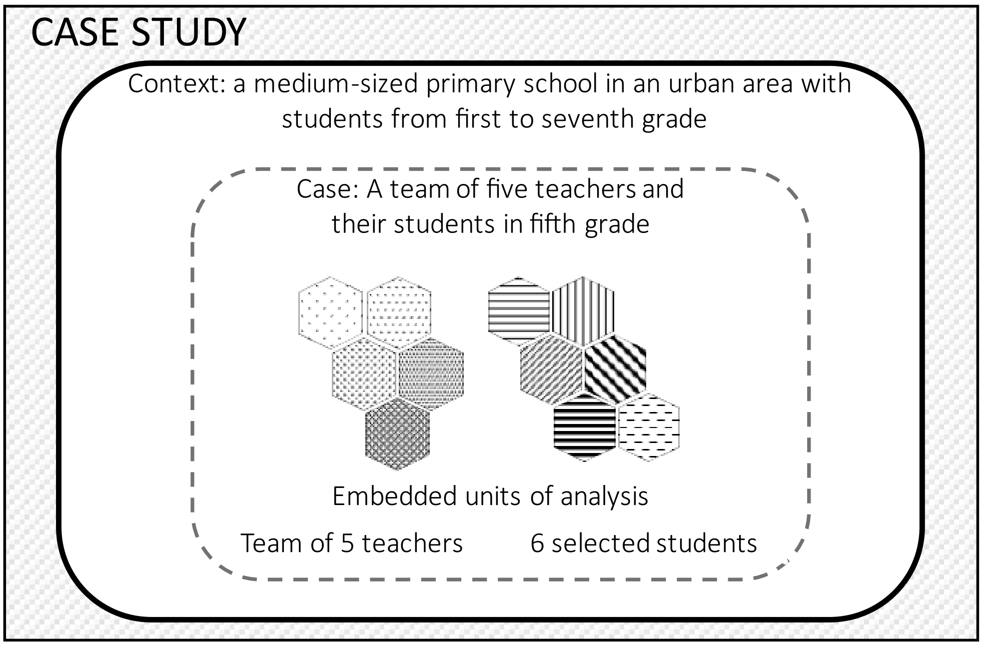


Figure 4: Case study with a single case design.

Choosing a case with a specific team of teachers and their students, makes it easier to bound the case. Bounding the case means clarifying, for instance, which persons to include in the case, distinguished from those who are not part of the case. In broader terms, it means to "distinguish data about the subject of your case study (the "phenomenon"), from data external to the case (the "context")" (Yin, 2018, p. 31). Here, the case study is limited to a team of teachers and their students in fifth grade and do not include the whole school. Thus, data concerning things like organization, schedules, or collaboration, across teams at the school level, are seen as external to the case and part of the context. Further, the case is limited to a time-period of two years, from the beginning of 2019 to the end of 2020.

According to Yin (2018), there may be several rationales for using a single-case design, like having a critical, unusual, common, revelatory, or longitudinal case. The main rationale for choosing a single-case design in this study is that of a common case, where "the objective is to capture the circumstances and conditions of an everyday situation" (Yin, 2018, p. 50). In Norwegian primary schools, teachers working together in interdisciplinary teams and thus jointly teaching all subjects at a certain grade, is a common way of organizing the work. Thus, a case with such an organization also fulfills the objective of capturing an everyday school situation.

An application to conduct the study was approved by the Norwegian Centre for Research Data in February 2019. All teachers and the students' parents signed an informed consent to participate in the study. The study started with a continuing education course for the participating teachers in spring 2019 and continued with the implementation of the teaching cases in the school through the schoolyear of 2019/ 2020. Due to the covid-19 pandemic some adjustments had to be made, and part of the implementation was postponed until the autumn of 2020.

9.4 Context and participants

The school is a medium-sized primary school in an urban area with students from first to seventh grade, which is located near the university where I teach biology in the teacher education program. There is an outdoor area between the school, the university, and the natural museum that is used for fieldtrips with students from both the school and the university. Students at the chosen school are familiar with this area and have had regular fieldtrips here since they started in first grade. The area contains among other things small meadows, a dead hollow oak, and some woodland. We used this outdoor area as an extended classroom in the study.

Picture 1: The outdoor area between the school, the university, and the natural museum

I have given the five participating teachers the following pseudonyms that I will use throughout the text: Tom, Lisa, Victoria, Thomas, and John. All have their teaching certificate, but otherwise they have different educational and professional backgrounds, and they range from 30 to 54 years of age at the time of the study. This means that they represent a diversified and interdisciplinary group of teachers. They all have some experience with teaching science but would not necessarily characterize themselves as science-teachers. Tom and Victoria have studied science as part of their teacher-education and John is originally educated as an engineer. In this context it should also be noticed that Tom has a special interest in biology and is a hobby mycologist. Lisa is a former preschool teacher and has some experiences from outdoor schooling. Thomas has his education from a time when there was no specialization in science in the Norwegian teacher education program. He teaches all subjects but has a special interest in music and mathematics (Table 3).

Table 3: An overview of the teachers that participate in the study.

	Year of birth	Main teaching subjects	Science as part of their education
Tom	1989	Science, Art and crafts	yes
Lisa	1974	English, Art and crafts	no
Victoria	unknown	Science, Norwegian, Physical education	yes
Thomas	1968	Mathematics, Music, English	no
John	1966	Mathematics, Arts and crafts (Woodwork), Special education	yes (as a former engineer)

All the students in fifth grade participated in the study. Morning meetings and fieldtrips were often conducted with all students collectively, but most of the time the 69 students were separated into three smaller groups during teaching lessons. In the project I followed one of the groups more closely, and from this group I chose six students whom I asked to participate in a sequence of three interviews. The selection of the six students was done after I had observed the students in the first period of the project. I wanted to include the silent and more introvert students as well as the talkative and more outgoing ones, the careful workers as well as the fast ones, and the ones that enjoyed drawing as well as the ones that did not. Thus, my aim was to select six students that represented a range, as I perceived it, in their response to the lessons and assignment based on the historical cases. In the end, I selected three girls and three boys that seemed to represent some of the diversity present in the group of fifth grade students. For practical reasons I chose six students that belonged to the same group, so that I could observe them at the same time.

Based on my observations in the classroom and my conversations with the students during the project-period, I will give a short description of some characteristics of each student that I think demonstrate how they represent the degree of diversity I was looking for. I have given the students the following pseudonyms that I will use throughout the text: Oliver, Sebastian, Peter, Mia, Emma, and Elise. Oliver and Sebastian are both outgoing and easily engaged, and they often respond to the teacher and ask questions aloud in front of the class. Sebastian loves group-work, while Oliver somehow struggles to cooperate with the other students. It seems to me that Oliver's struggle has to do with a strong engagement and a vision of how things should be that may be difficult for him to adjust when confronted with other opinions. At one point, in the middle of a group work about the life cycle of different butterflies, Oliver suddenly wanted to leave the group to make his own project about the silkworm (which he was deeply fascinated by). Sebastian on the other side is most of all engaged in the social interactions of the group work, maybe more than in the task itself, and simply seems to like being together with other students. Peter is quieter than both Sebastian and Oliver, and seldom raises his hand in the classroom. Still, it seems to me that he is very attentive to what is being said and generally engaged in the given tasks. He is quite concentrated, serious, and thoughtful. Mia on the other hand seems rather unfocused and easily distracted at times. She may raise her hand in the classroom and engage herself in discussions but like to finish her tasks rather quickly. She is eager to run out and play during the breaks. Both Emma and Elise are quieter and also kind of serious. Emma draws carefully and likes to use many different colors when she works with the different tasks in the booklet. She seldom raises her hand in class, but still has rather strong opinions about how she wants to do things in groupwork, for instance. Elise always works with her tasks very thoroughly. She might raise her hand in class but talks with a very low voice.

According to Yin (2018, p. xxxi) case studies require several steps to: plan, design, prepare, collect, analyze, and share. In this chapter I described the plan and design of my case study. In the next chapter I will describe how I collected and analyzed material in the case study in two phases.

10 Methods of collecting and analyzing material in the case study

In this chapter, I will describe the implementation of the teaching cases in the continuing education course for teachers in phase two and the implementaion of the same teaching cases in the classroom with students in phase three. Further, I will describe the methods for collecting material and how I have conducted the analysis in both phases.

10.1 Continuing education course for teachers

Phases two and three constitutes the case study with teachers and students in fifth grade. Phase two describes the implementation of the historical teaching-cases into the continuing education course for the five teachers participating in the case study (Figure 5). In phase two of my investigations the research question is:

> How do teachers experience the practice of observing living nature in the context of teaching and learning science in primary school?

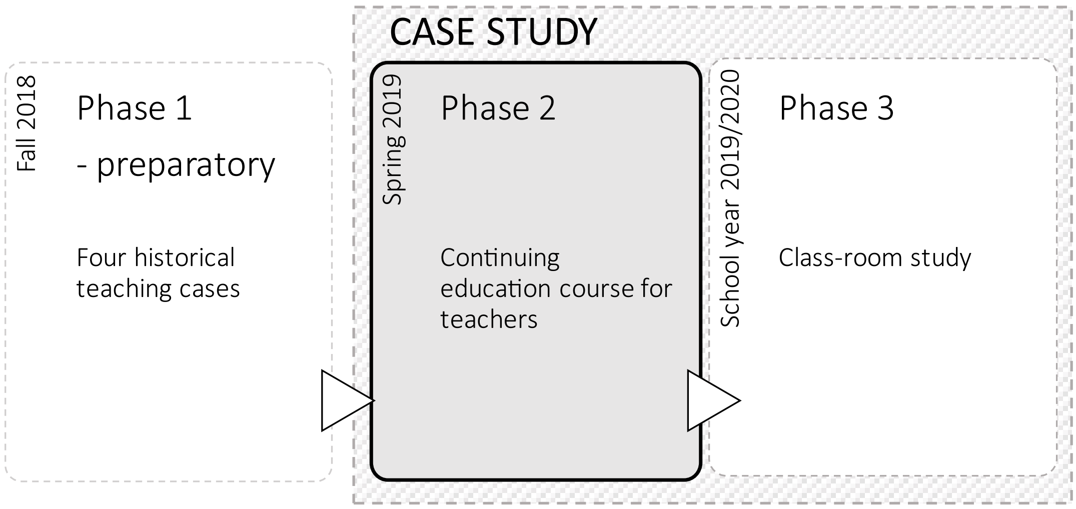


Figure 5: Phase 2 - Continuing education course for the five teachers participating in the case study.

10.1.1 Implementation

In phase two, the aim was to implement a continuing education course for teachers based on the four teaching cases from the history of science that demonstrate complementary ways of observing biological diversity (Lien, 2019).

The course was implemented in spring 2019. I instructed the course myself and the participants were the five teachers described earlier. Based on the four selected cases from the history of science and my analysis, I made a booklet for the teachers where I presented each case. For each case, I described the time-period, the person who made the observations, the questions leading up to the investigations, and the way in which the observations were conducted. In the course, each case was linked to practical exercises inside and outside of the lab, and focused on practicing the skill of observing, in relation to, respectively describing, systematizing, and explaining living nature (see lesson plan, Table 4).

Table 4: An overview of the completed lesson plan for the continuing education course.

	Shifting observational practices	Instructional activities to support related practices.
	Introductory lesson-Interdisciplinary in observational practices	The teachers attended part of an interdisciplinary course with teacher-students called: What is observation? Examples of scientific, artistic, historical, and didactic perspectives related to the observation of biological diversity. (5h)
Case 1	Observations based on comparison	**Lesson 1:** Telling the story of Aristotle as an introduction to discovering nature. Observational exercises to investigate woodlouse and earthworm. Individual reflection log. (3h) **Lesson 2**: Observational exercises to practice comparing and recognizing central orders of insects. Individual reflection log. (3h)
Case 2	Observations based on aesthetical and holistic experiences.	**Lesson 3:** Fieldtrip to a local lake to practice recognizing various deciduous trees and listen to and observe birds. (8h) **Lesson 4:** Telling the story of Merian and her aesthetical and holistic mode of observation. Observational exercises to make an illustration of a chosen butterfly and its life cycle. Individual reflection log. (3h)
Case 3	Observations based on analysis and systematics.	**Lesson 5:** Telling the story of Linné and his systematic and analytical mode of observation. Observational exercises to recognize flower parts and central families of plants. Individual reflection log. (3h)
Case 4	Observations based on synthesis and explanations	**Lesson 6**: Telling the story of Wallace and Darwin, and theory of evolution. Exercises that demonstrate natural selection (Clipbirds). Individual reflection log. (3h)
	Comparing observational practices	**Lesson 7**: Conclusive remarks on scientific processes and observational practices in science education. Group discussion and evaluation of the course. (3h)

10.1.2 Methods for collecting material

My material consists of teachers' reflection logs after each lesson, course evaluation survey and interviews. According to van Manen (2016b):

> The point of phenomenological research is to "borrow" other people's experiences and their reflections on their experiences in order to better be able to come to an understanding of the deeper meaning or significance of an aspect of human experience, in the context of the whole human experience (p. 62).

The aim of gathering texts from different genres was to obtain such experiential descriptions from the teachers. In addition, I engaged with the participants as their teacher during the course. According to Greenwalt (2008) engagement with participants, whose texts are gathered and analyzed, may be seen as the primary research method. It may help the researcher to better understand the significance of the participants experiences.

During the course, the teachers wrote six personal logs each (Appendix A), and on the last day of the course they answered questions about the content of the course in a written document (Appendix B). These texts were part of my preparation for the interviews which were conducted within a couple of weeks after the course ended. The individual, in-depth, interviews were semi-structured and based on an interview-guide (Appendix C) (e.g. Kvale & Brinkmann, 2015). The main categories in the interview guide were observation and how it interacts with describing, systematizing, and explaining living nature. The teachers were also asked about the role of the history of science and scientific practices in education, and about the species concept. In addition, the interview guide was partly individually customized by asking some questions based on what the participants had written in their logs that seemed significant to me within the scope of this study. These individual questions were noted in the right column of the interview-guide in connection to the related categories. For example, Thomas was asked to elaborate on what he meant in his first log by writing "there may be different opinions on what is relevant or irrelevant" in an observation. All interviews were transcribed by me, and these transcripts were used for the analysis.

The interviews aimed at achieving a phenomenological approach and the questions focused on the teachers' experiences with the phenomenon either in the course or in their own teaching. The teachers were asked to think of specific instances and situations, but also reflect on the meanings of the experiences. Seen in retrospective, the distinctions between questions for the purpose of either gathering or reflecting on lived experience could have been even clearer. As van Manen (2016b) underscores it may be helpful to keep these two functions of the interview in mind. For example, all teachers were asked in the beginning of the interview: "What significance do you think observation may have in learning about biological diversity like plants and animals?" To ask about the significance of something could invite more to reflecting on than to describing experiences. Instead, I could, for instance, have asked them to describe their experiences with observing plants and animals in general as an opening question. To amend this, I tried during the analysis to be aware of if the teachers were either reflecting on experiences or describing them. I some cases, statements that primarily were reflections were marked in purple text instead of red. In my descriptive comment in red to the right I wrote "Reflects on own experience -" before describing the content (Figure 6).

- Noe du ville ha gjort annerledes, noe du ville ha endret på eller ...? Ja … kanskje ventet enda lenger på den forklaringsdelen egentlig, en er jo fort litt raskt ute ... Ofte blir det bare forsøk i starten av timen og forklaring på slutten. Kanskje en skulle ha venta enda litt lengre med forklaringen, bruke lengre tid på selve prosessen observasjon og beskrivelse ... - Hvorfor tenker du det? Eller hvis du bare utdyper det? Det er jo en større del av naturfaget også da, egentlig, selve prosessen ..., men det er mye læring i den også. Motivasjonen for å finne forklaringen … jo mer tid det går også, og hvor mer man får forsøkt det ... Forholdet man får til selve forsøket først, eller den observasjonen.	Reflekterer over egen erfaring – kunne ventet enda lengre med forklaringen, brukt lengre tid på selve prosessen. Motivasjonen for å finne forklaringen hadde kanskje økt. #11 Explanations may stop the exploration.

Figure 6: Transcript excerpt with my comments to the right.

10.1.3 A phenomenological analysis of the teachers' experiences

In the overall analysis I followed the systematic steps in the simplified version of phenomenological analysis described by Moustakas (1994), as presented in Creswell and Poth (2018, pp. 201-202). In the following I will discuss this approach in relation to van Manen's less structured combination of descriptive and interpretive approach. Part of this method of analysis was also described in an unpublished exam paper authored by me (Lien, 2020). I will elaborate on three main aspects of my research process: 1. Unbiased reading, 2. Theme development and 3. Reflective writing.

Unbiased reading

According to the first step in the simplified version of Moustakas method, I described my own experience with observing living nature in the introduction to this thesis, with an attempt to set this aside so that my focus can be directed toward the participants (Creswell & Poth, 2018). In phenomenology, the term bracketing is used to describe the process of placing one's knowledge and pre-understanding outside of the phenomenon. van Manen (2016b) writes that "it is better to make explicit our understandings, beliefs, biases, assumptions, presuppositions, and theories", not in order to forget them, but to keep them at bay (p. 47). However, what bracketing means in the research process and at what stage it should occur has been highly disputed (e.g. Dowling, 2007). Another term for bracketing one's knowledge and pre-understanding is reduction, described in the original works of Edmund Husserl. To Husserl reduction and the *epoché* (suspension) is central to practicing phenomenology (van Manen, 2016a). The process has been understood in various ways by different interpreters, but "the basic idea of the *epoché* and reduction is to return to the world as we live it in the natural attitude"(p. 222). This means that the *epoché* and reduction is an attitude, rather than a method or a stage in the research process. Van Manen distinguishes between four aspects of the *epoché*: wonder, openness, concreteness and approach. About wonder he writes: "In wonder we see the unusual in the usual, the extraordinary in the ordinary." (p. 223). This aspect of the reduction consists of bracketing the attitude of taken-for-grantedness.

In my analysis, I have tried to approach the participants lived experience with a sense of "newness", read the interview transcripts open-mindedly and look for the teachers' own experiences, while keeping my own pre-understandings at bay. In addition, I have looked for what might be extraordinary in the ordinary of observing living nature, and as a researcher tried to be "receptive and awakened to a profound sense of wonder" (van Manen, 2016a, p. 224) throughout the inquiry process.

Developing themes

The next steps in the simplified version of the method of Moustakas are to, first, develop a list of significant statements and, then, to group these statements into larger units called meaning units or themes (Creswell & Poth, 2018, pp. 201-202). In my analysis this was a hermeneutical process of going back and forth in the transcript, reading and reflecting on both the whole and the parts. In the process I recognized some of the procedures for reflection and achieving general findings that are identified in the practice of phenomenological reflection (e.g.Wertz et al., 2011, pp. 132-133). First, I read the whole interview slowly without making any comments. In the second reading, I started to highlight statements that I considered to be significant. I used what van Manen (2016b) calls a selective reading approach in the process of isolating thematic aspects in the text, and asked "what statements or phrases seem particularly essential or revealing about the phenomenon?" (p. 93). In the third reading, I wrote descriptive comments in the right margin in red, to summarize expressions of either experiences, or reflection of experiences. In addition, I wrote interpretive comments and questions in the same margin in light blue. The interpretive comments were based on retrospective reflection and explored what was revealed about the phenomenon. In these comments, I pointed to connections between statements and to some implicit meanings. When the statements were unclear to me, I formulated questions. In the *fourth* reading, I started to look for patterns and connections across my notes, going back and forth, and formulate emergent themes to capture central aspects. Emergent themes were written in dark blue in the same margin as the other comments (Figure 7).

Men i sosialpedagogikken der tolker vi ansiktsuttrykk og tenker en situasjon, kanskje en gutt ligger på bakken og har blod på kneet og er lei seg og ... Så det er jo veldig enkelt i så måte, de er jo lagd for at ungene skal kjenne seg fort igjen i de. Nå tenker jo ... Det er jo vanskelig å få med når en er ute og observerer i naturen på en måte for en er jo mye mindre vant med det sjøl, du ser ikke noe ansiktsuttrykk eller bøyd nakke eller ...	Ungene kjenner seg igjen i situasjonsbildene, det er vanskeligere når vi er ute i naturen – «du ser ikke noe ansiktsuttrykk». Han peker på utfordringen med å få en relasjon til naturen/ andre levende organismer. Handler det om empati? #6 Lack of facial expressions in nature

Figure 7: Transcript-excerpt with my comments and emergent themes to the right

Some of the emergent themes were recurrent and related to several statements in the transcript, some only occurred once. In the end I made a list of emergent themes in a new table and started to develop overall themes to express the essence of the experience and point to meanings (Figure 8).

Transcript Thomas	Emergent themes	Themes – point to meanings of the experiences (van Manen) - *find implicit dimensions and intuitions (Finlay)*
s. 6	#6 Lack of facial expressions in nature	The *things* teachers observe in living nature.
s. 28	#16 What is a species? The species concept is vague.	
s. 9	#7 To practice describing change the observation.	To practice the skill of observation is complex and correspond with describing, systematizing, and explaining.
s. 13, 14	#8 To make systems is fundamental and creates meaning.	
s. 5	#4 Explanations should be anchored in observations	
s. 15	#9 Observations are the foundation for explanation	
s. 16	#10 Explanations and why-questions beforehand, may limit observations	

Figure 8: Excerpt from the table showing emergent themes and the developing overall themes.

After reading the first interview transcript following this procedure, I followed the same procedure reading the next transcripts. In the end, I gathered emergent themes from all the teachers' experiences in the same table with references to the pages with the specific statements in the interview-transcripts. Excerpt from this table is shown in Figure 9.

Transcript L5 – John L4 – Thomas L3 – Victoria L2 – Lisa L1 -Tom	Emergent themes	Themes – point to meanings of the experiences (van Manen) - *find implicit dimensions and intuitions (Finlay)*
s. 6	#6 Lack of facial expressions in nature"	*What are the 'things' we observe? The nature of living nature.*
s. 28	#16 What is a species? The species concept is vague.	
s. 27, 28, 29, 30	#19 What is a species? The species concept is vague.	
s. 28, 30, 31	#12 What is a species? The species concept is vague.	
s. 21, 22	#15 What is a species? The species concept is vague.	
s.5	#3 Observation gives access to what is actually there	
s. 6	#5 Observation is of something concrete	
s. 4	#2 Living nature is vast	
s. 4, 13, 14	#3 Living nature reveal new things when you start to look, there is always something more	

Figure 9: Excerpt from the table showing references to transcript, emergent themes and corresponding overall themes from all the interviews.

As the list of emergent themes developed, I reformulated the overall corresponding themes several times to try to identify general and essential features. In the end, I arrived at four overall themes that I think describe essential aspects of the phenomenon of observing living nature in the context of teaching and learning science in primary school. These four themes will be presented in Part IV. However, the themes were only points of departure from which phenomenological description was facilitated.

Reflective writing

The last two steps in the simplified version of the method of Moustakas are to create descriptions of what the participants experienced, and how they experienced it, and then write a composite description of the phenomenon (Creswell & Poth, 2018). According to van Manen (2016b), “the aim of phenomenology is to transform lived experience into a textual expression of its essence” (p. 36). The challenge is that describing lived experience is not straightforward, and “what ‘appears’ is not at all something apparent or clear-given” (van Manen, 2016a, p. 61). In my analysis, descriptions and interpretations of the teacher’s experiences may be an affirmation of the teacher’s tacit knowledge but may also challenge what is taken-for-granted. According to Henriksson (2012), phenomenology “holds a promise of both proximity and distance, the familiar and the alien, the known and the not yet known” (p. 3). It means that the descriptions should both be close to the teachers’ practice and experience, and at the same time, try to see something new and describe something not yet described.

To me, retaining a phenomenological attitude in the process of reflective writing is balance between using my own pre-understandings and experiences, and staying open to how the teachers’ experiences might expand or question these understandings. Further, there is a balance between expressing essential features with the phenomenon and trying to avoid abstractions. In the process, I used the table with the emergent themes from all the interviews, and the corresponding themes that were the result of the analysis (Figure 9). For example, the table helped me to get an overview of emergent themes from all five interviews related to Theme 1, and at the same time, the corresponding references to the teacher’s statement helped me to stay close to the teacher’s experiences. In the descriptions of themes presented in Part IV, I use significant statements from all the teachers, and point to what the meaning or implicit dimensions of these statements might be.

To assist the reflective writing, I considered the existential and universal themes of lived things, lived body, lived relation, lived space and lived time (van Manen, 2016a, p. 302). In this case, living nature belongs to the existential theme of the lived things that make up our world, while the practice of observation and interaction of skills are connected to the universal themes of lived body and lived space and time.

10.2 Classroom studies with teachers and students

Phase 3 describes the implementation of the historical teaching-cases into the classroom with teachers and students participating in the case study (Figure 10). In phase 3 of my investigations the research question is:

> How do 5th grade students experience different modes of observing living nature demonstrated through four cases from the history of science?

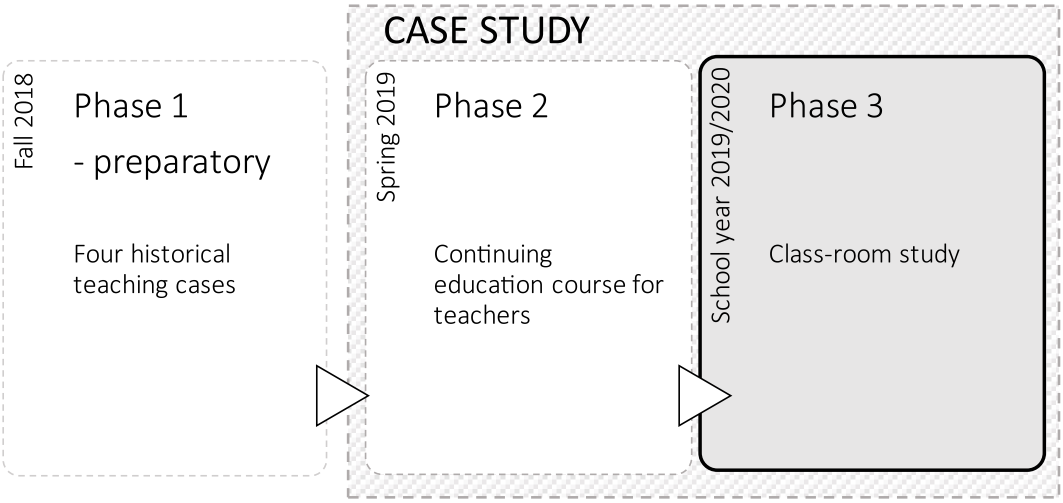


Figure 10: Phase 3 - Implementation of historical teaching cases in the classroom.

In this phase, the aim was to implement the four teaching cases developed in phase 1 in fifth grade in the selected school. The cases were implemented as four defined projects during the schoolyear 2019/2020, however, due to the Covid-19 pandemic, the implementation of the last case was postponed until autumn of 2020. I was present during most of the teaching related to the project as a participate observer.

The five teachers taught their students based on their own experiences from the continuing education course in phase two. However, at the teachers' request, I made small booklets for each case intended for the students (QR-codes that links to these booklets are presented in part IV). In the booklets, in the same way as with the booklet for the teachers, each case presented a time-period, the person who made the observations, the questions leading up to the investigations, and how the observations were conducted. However, there was obviously much less text than in the teachers’ booklets, and the language was adapted to the students. The booklet for the students also contained questions for discussion, spaces for filling in answers, and practical exercises. Thus, during the implementation of the four cases in school, the students experienced various indoor and outdoor observational practices, partly designed by me and partly by the teachers (Table 5).

Table 5: *An overview of the completed lesson plan for the classroom teaching in Phase 3.*

	Shifting observational practices	Instructional activities to support related practices.
Case 1	Observations based on comparison. Booklet I: *How to observe nature? Aristotle's method.*	**Lesson 1:** Telling the story of Aristotle. Discussing what parts all animals have. Asking questions about earthworms. **Lesson 2***:* Making a terrarium for earthworms. Observational exercises to investigate earthworm. Reporting in the journal. **Lesson 3***:* Observational exercises to practice comparing and recognizing seven insects representing central orders of insects. Observing both pictures and specimens.
Case 2	Observations based on aesthetical and holistic experiences. Booklet II: *How to observe nature? Merian's butterflies.*	**Lesson 4***:* Telling the story of Merian. Practicing an exercise about what Merian saw, heard, and smelled in the painting studio of her stepfather. **Lesson 5, 6, and 7**: Observational exercises to make a shoebox diorama of all the stages in the life cycle of a chosen species of butterfly inspired by Merian's drawings. **Lesson 8:** Exhibition of the students' dioramas.
Case 3	Observations based on analysis and systematics. Booklet III: *How to observe nature? Linné's system.*	**Lesson 9**: Telling the story of Linné. Discussing what it means to be systematic. Make drawings of Linné's office. **Lesson 10**: Field trip to a nearby meadow. Practicing two observational exercises: 1) Open observation and making notes in the journal. 2) Collect and observe plants to practice recognizing flower parts and central families of plants. **Lesson 11**: Linnè's classification system for plants. Referring to plants observed at the fieldtrip. Drawing an imaginative flower including all the flower parts.
Case 4	Observations based on synthesis and explanations. Booklet IV: *How to observe nature? Wallace's and Darwin's explanation.*	**Lesson 12**: Telling the story of Wallace and Darwin, their travels around the world and the development of a theory of evolution. **Lesson 13**: Fieldtrip to the Natural History Museum. Practicing two exercises: 1) Watching the exhibition *Microsculpture*[22]. Drawing and describing a chosen insect. 2) Using model clay to make a fantasy animal in three stages of development. **Lesson 14**: Observational exercise comparing photos of different legs of beetles and different beaks of birds and discuss what might be the explanation for these differences. **Lesson 15**: Introducing the species concept. **Lesson 16**: Making a podcast about Wallace and Darwin

[22] Microsculpture is a project by the British photographer Levon Biss that presents insect specimens from the Oxford University Museum of Natural History http://microsculpture.net/microsculpture.html

To implement the four cases in their teaching the teachers cooperated across subjects. Several of the observational exercises they conducted with the students were interdisciplinary. For instance, while working on the case about Merian, one of the student tasks was to present the life cycle of a specific species of butterfly in a shoebox, like a diorama. It was a group-task where the students made both the butterfly, larvae, egg, and hostplant in a three-dimensional space, and the task included the subjects: arts and crafts, science, as well as reading in Norwegian.

10.2.1 Methods for collecting material

The material for my analysis consists of notes and photos from participatory observation (e.g. Fangen, 2010) in the classroom, students' work (like answers and drawings in booklet and journal), and individual, semi-structured, in-depth interviews with six students (audio-recorded and transcribed).

Before the observation in the classroom started, I made an observation-guide (Appendix D). I wanted to observe the teachers' practice in the classroom and the students' response to this practice, concerning the phenomenon of observing living nature. My observation in the classroom was intended to contribute to a more holistic understanding of both the teachers' practice and the students' response to this practice. Therefore, during observation, I tried to notice to things that are not easily conveyed in an interview. For instance, how materials and equipment in the classroom create opportunities or obstacles for the teachers' practice. Another observational focus was how the teachers' practice is visible in non-verbal and embodied ways, like how they demonstrate observation, how they point to what is important, and give non-verbal response to what is significant in the students' observations. Yet another focus was how the teachers' practice conveys a certain understanding of what science is. Observing the teachers in the classroom gave me an opportunity to compare what the teachers said in an interview with what they did in the classroom. Therefore, I developed an observation guide with three columns that represent three different dimensions of the teachers' practice: 1. physical space and materials, 2. embodied practices, and 3. how the teachers demonstrate science. However, when I took notes during a lesson, I did not use the guide as a scheme. Instead, I made notes in a notebook where I had one column for time, one column for the lesson plan (in keywords), and a third column for my descriptive comments and question about what happened in the different parts of the lesson. After the lesson, I wrote a reflection log where I tried to formulate what seemed significant to me, while having in mind the three dimensions of the teachers' practice described above.

My experiences and notes from the observation in the classroom were mainly used to design the interviews I had with both the teachers and students during and after the implementation of the four cases in school. The observations helped me to stay close to their lived experience as teachers and students and also made it possible for me to customize the interview guides by including specific incidents from the classroom. In addition, I brought with me the experiences from phase two and the interviews and conversations I already had with the teachers. Based on these experiences and a preliminary analysis of the teacher interviews in phase two, I formulated four overall categories that I used as categories in both the teachers' and students' interview guide in phase three (Appendix E and F). These categories were based on the four main themes from the interviews with the teachers in phase two. Based on Theme 1: "You do not see any facial expressions in nature", I formulated an overall category of "What are the 'things' we observe in living nature?". Based in Theme 2 "You have to know what to look for, so you don't just look for anything that doesn't matter", I formulated an overall category of "To practice the skill of observation". Based on Theme 3 "Being a teacher is to explain", I formulated an overall category of "The role of the teacher in observation". Based on Theme 4 "You must know enough to see what you see", I formulated an overall category of "Observation as part of a scientific practice".

This means that in each student interview, I formulated questions that related to these overall categories. For instance, relating to the overall category "what are the things we observe in living nature", I asked the students to describe specimens and pictures of living organisms that I had brought along, and to answer the question of what makes something living. Doing research with children requires a combination of several methods for capturing children's perspectives and often entail task-based methods (Punch, 2002; Randall, 2012). The interviews were customized to each student by bringing in things they had said or done during class while working with the different cases, and by letting them describe and comment their own work in the booklets or journal.

10.2.2 A phenomenological analysis of the students' experiences

In the analysis of the interviews with the students, I followed the same steps as I did when I analyzed the interviews with the teachers (see section 10.1.3). However, when developing themes from the students' interviews, I had in mind the four themes I already had developed to describe the teachers experiences of the phenomenon of observing living nature. Furthermore, the interview guide for the students' interviews (as described in the previous section) was partly designed by the categories based on the themes developed from the teachers' interviews. After reading the interviews with the students, I developed a list of significant statements, and grouped these statements by the overall categories. The themes that emerged from the interviews with the students, seemed to mirror or respond to the themes from the interviews with the teachers. Thus, I formulated and described four themes (Themes 5, 6, 7 and 8) to describe the students' experience with the phenomenon of observing living nature, one theme relating to each of the four themes describing the teachers' experiences.

10.3 An overview - steps of implementation, collection, and analysis.

In Part III, I have described my methods of investigation and analysis in three phases. First, I prepared and implemented the case study in three phases (Table 6, first column). In phase one, I selected and prepared four historical teaching cases by analyzing historical sources. In phase two, I implemented the four teaching cases into a continuing education course for the five teachers that were part of the case study. Based on experiences form phase two, the teachers implemented the same historical teaching cases in the classroom with students in fifth grade in phase three.

Second, I collected material in three phases (Table 6, second column). In phase one, I collected both primary and secondary documents about the selected historical cases to prepare the historical teaching cases. In phase two, during the continuing education course, I collected the teachers' reflection logs from each lesson, the teachers' answers to a course evaluation survey, and audio recording of the teachers' group conversation during the last session. Based on this material I prepared and conducted individual, semi-structured, in-depth interviews with the five participating teachers at the end of the course. The interviews were audio-recorded and transcribed. In phase three, during the implementation of the four historical teaching cases in the classroom, I took notes and photos from my own participatory observation in the classroom, and collected students' work, such as answers and drawings in their booklets and journals. Based on this material, I prepared and conducted individual, semi-structured, in-depth interviews with six selected students three times during the period. In addition, I prepared and conducted individual, semi-structured, in-depth interviews with the five participating teachers at the end of the period. Alle interviews were audio-recorded and transcribed by me.

Third, I analyzed the collected material in three phases (Table 6, third column). In phase one, I analyzed the historical documents to extract fundamental questions and types of observational practices in each case. In phase two, I performed a phenomenological analysis of the interviews with the participating teachers to develop themes that describe essential experiences with the phenomenon of observing living nature in teaching and learning. In phase three, I performed a phenomenological analysis of the interviews with both the participating teachers and the six selected students, to further develop themes that describe essential experiences with the phenomenon of observing living nature in teaching and learning. The results of the analysis from each phase will be presented in Part IV.

***Table 6:** Steps of implementation, collection, and analysis in three phases.*

	Implementation	Material collected	Analyzes
Phase 1	Preparing historical teaching cases	• Primary and secondary historical sources about the observational practices related to each case.	Historical analysis to extract fundamental questions and type of observational practice, in each case.
Phase 2	Implementation of historical teaching cases (from Phase 1) in a continuing education course.	• Teachers' reflection logs to each lesson • Teachers' answers to a course evaluation survey • Teachers' group conversation during the last session • Individual, semi-structured, in-depth interviews with five teachers (audio-recorded and transcribed)	Phenomenological analysis of interviews to develop themes that describe essential experiences with the phenomenon observing living nature.
Phase 3	Implementation of historical teaching cases in the classroom (based on experiences from Phase 2).	• Notes and photos from participatory observation in the classroom. • Students work - answers and drawings in booklet and journal. • Individual, semi-structured, in-depth interviews with five teachers and six students (audio-recorded and transcribed)	Phenomenological analysis of interviews to develop themes that describe essential experiences with the phenomenon of observing living nature

PART IV: Results

In this part, I will describe the results of my analysis as described in Part III. In Phase 1, the preparatory phase, I have analyzed the selected historical cases to describe modes of observation in history and to design historical cases for teaching. In Phase 2 and Phase 3, the case study, I have analyzed interviews with teachers and students to describe modes of observation in teaching and learning. In Chapter 11, I describe four modes of observation from the history of science to answer research question 1:

> How might cases from the history of science be designed to strengthen teachers' and students' observational practices and knowledge about living nature?

In Chapter 12, I describe themes based on both the teachers and students' experience with different observational practices based on the four teaching cases designed in Phase one, to answer research questions 2 and 3:

> How do teachers experience the practice of observing living nature in the context of teaching and learning science in primary school?
>
> How do 5th grade students experience different modes of observing living nature demonstrated through four cases from the history of science?

11 Modes of observation in history

> The boundaries of species are as men, and not as nature makes them. (John Locke, 1690 in Sloan, 1972)

In this chapter I will present the results of my analysis of the historical sources described in Chapter 8. In order to design teaching cases that demonstrate different observational practices, I have analyzed the historical sources in three steps by: 1) finding a fundamental question in each case that conveys the intentional objective with the described observational practice, 2) extracting a typology of observational practices based both on the fundamental questions in each case and the practices applied by the central actor to answer the same question, and 3) comparing and discussing the different questions to find what the central actors perceived as being relevant observations in living nature in each case. I will elaborate on the results from each of these three steps in the following sections. Finally, based on this analysis, I will discuss how teaching cases from the history of science may be designed, and I will suggest a general structure for designing such teaching cases.

11.1 Fundamental questions and observational practices in four cases

My selection process led to four historical cases. I have defined four fundamental questions and extracted four types of observation from the selected historical cases and called these types of *modes of observation*. I will give an overview of the results in terms of which fundamental questions are asked and which observational practices are applied to answer the defined questions and demonstrate with some examples.

I will argue that the central actors in each case explored nature according to the following questions:

I. Aristotle: What is the essence of this living organism?
II. Merian: How can we describe living organisms according to their nature?
III. Linné: How can we systematize the diversity of living organisms?
IV. Wallace and Darwin: How can we explain the diversity of living organisms?

Thus, each case starts from a central, but different question, and connects an observational practice to specific phenomena in living nature. The central actors explored phenomena like orders of insects, the life cycle of butterflies, classification of plants, and the dynamic and changing nature of species. The changing questions in the historical exploration of living nature may reveal what was perceived as relevant to observe.

11.1.1 Case I: A comparative mode of observation

Aristotle was the first person that we know of to investigate living nature systematically. In this case, I will argue that the fundamental question is: *What is the essence of this living organism?* Aristotle was a great philosopher and argued that all living organisms are fascinating in themselves. He looked for the essence or *eidos* of each type, or species, based on a *comparative* mode of observation.

The important first step in Aristotle's comparative mode of observation was that he stated that all living organisms, even the "humbler animals", may reveal something important about nature, and that "every realm of nature is marvelous" (Aristotle, 1990b, pp. 169, 645a):

> We therefore must not recoil with childish aversion from the examination of the humbler animals. Every realm of nature is marvelous: and as Heraclitus, when the strangers who came to visit him found him warming himself at the furnace in the kitchen and hesitated to go in, reported to have bidden them not to be afraid to enter, as even in that kitchen divinities were present, so we should venture on the study of every kind of animal without distaste; for each and all will reveal to us something natural and something beautiful (p.169, 645a).

Further, Aristotle discusses methods for observing and recognizing natural groups of animals. He underscores that no single criteria "can possibly express the essence of a species" (p. 167, 644a), and he argues that "it is impossible then to reach any of the ultimate animal forms by dichotomous division" (p. 167, 644a). Instead, he presents this method:

> The method then that we must adopt is to attempt to recognize the natural groups, following the indications afforded by the instincts of mankind, which led them for instance to form the class of birds and the class of

> fishes, each of which groups combines a multitude of differentiae, and is not defined by a single one as in dichotomy (p. 167, 643b).

Thus, to recognize what Aristotle calls the natural groups of animals, and ultimately the essence of a species, we must compare several criteria of differentiation. In the following quote, he further describes how:

> We have, then, first to describe the common functions, common, that is, to the whole animal kingdom, or to certain large groups, or to the members of a species. In other words, we have to describe the attributes common to all animals, or to assemblages, like the class of birds, of closely allied groups differentiated by gradation, or to groups like man not differentiated into subordinate groups. In the first case the common attributes may be called analogous, in the second generic, in the third specific (p.169, 645b).

According to Aristotle there are three steps, or levels, of observation and comparison: 1) to describing and comparing common analogous attributes or parts in all animals, 2) describing and comparing common attributes within a group, for instance insects, birds or fish, and 3) describing and comparing specific attributes or parts within a species. The compiled observations are summarized by defining an essence; that is, the common qualities shared by all the cases investigated, within either all animals, a group (like insects or birds), or a species.

The three levels of comparison describe a pragmatic way of observing the overwhelming diversity of living organisms. To first compare and describe analogous parts common to all animals, means that we *as investigators of nature* do not have to repeat these common features when we are describing, for instance, insects as a group. Describing insects as group, we can concentrate on describing the parts that all insects have in common, and at the same time separate insects from other groups. Further, we may compare how these parts (although in common) differ in grade, to separate different groups of insects. The last step would be to find the essence of a species by describing its specific traits, i.e., traits that are common to all individuals belonging to the species, and which, at the same time, separate this species from all other species. Such specific traits must be traits that are different from the generic traits common to all insects.

To describe the essence of a species, or what Aristotle calls *eidos*, means to describe not only the structure of a certain organism, but also the form of different parts, and the function these parts have. In Aristotle's view, there must be a reason for how the animal's parts are formed to serve the organism as a whole. To exemplify, he uses a description of a couch as a metaphor:

> For we should not be content with saying that the couch was made of bronze or wood or whatever it might be, but should try to describe its design or mode of composition in preference to the material; or, if we did deal with the material, it would at any rate be with the concretion of material and form. For a couch is such and such a form embodied in this or that matter, or such and such a matter with this or that form; so that its shape and structure must be included in our description. For the formal nature is of greater importance than the material nature (p. 163, 640b).

And further:

> … the true method is to state what the definitive characters are that distinguish the animal as a whole; to explain what it is both in substance and in form, and to deal after the same fashion with its several organs; in fact, to proceed in exactly the same way as we should do, were we giving a complete description of a couch (p. 163, 641a).

In other words, describing an animal means describing the definitive characteristics in both structure and form that distinguish a specific animal from other animals, and also, how these features serve the animal as a whole.

Aristotle`s description of the form and function of insect wings, in the quote below, demonstrates how he compared common attributes within a group. The wings are common to all insects, but they differ in design and function. The description also gives insight into the details of the way he observed:

> Of such flying insects some live a wandering life and are forced to make long expeditions in search of food. These have a body of light weight, and four feathers, two on either side, to support it. Such are bees and the insect akin to them. When, however, such insects are of very small bulk, their feathers are reduced to two, as is the case with flies. Insect with heavy bodies and of stationary habits, though not

> polypterous in the same ways as bees, yet have sheaths to their feathers to maintain their efficiency. Such are the Melolonthae and the like. For their stationary habits expose their feathers to much greater risks than are run by those of insects that are more constantly in flight, an on this account they are provided with this protecting shield. (Aristotle, 1990b, pp. 213, 682b).

In the same way, Aristotle described and compared the number of segments in insects, and the differentiation of insects' mouthparts and legs. In these descriptions, Aristotle includes interpretation when he suggests explanations for why the parts of an animal have a certain form, like he does in the description of insect wings. In another book *The History of animals*, he does not include interpretations of function, only descriptions of the building and form of an animal's parts (Aristotle, 1990a). This means that Aristotle made a clear distinction between descriptions with and without interpretations and explanations.

Thus, Aristotle demonstrates a comparative mode of observation to answer the fundamental question: *What is (the essence of) this living organism?* To Aristotle, the essence or *eidos* is not a single criterion or a general idea, but something we can find only by observing and comparing different animals and using several criteria. Importantly, *eidos* is understood as something more than an animal's morphological traits and has to do with the form and function of the animal as a whole. It might be argued that eidos could be understood as a unique way of being in the world.

11.1.2 Case II: A holistic and aesthetical mode of observation

Maria Sibylla Merian was part of the developing sciences of describing nature in the Renaissance. In this case, I will argue that the fundamental question is: *How can we describe living organisms according to their nature?* Merian was both a painter and a naturalist. She sketched detailed, naturalistic drawings and paintings of specific caterpillars and butterflies, also depicting their metamorphosis and interaction with the forage plant. Her descriptions were based on a *holistic* and *aesthetical* mode of observation.

Merian wrote that she wished “to draw and describe them all according to nature”, and stated that “I have kept simply to my observations” in the preface to her book *Transformations of Surinamese Insects* from 1705 (Friedewald, 2015, pp. 120, 121). Merian collected and studied caterpillars from a very young age. She developed a deep fascination for these animals that lasted throughout her life, although she was not allowed as a woman to study natural science at the university. All her drawings were based on her own investigations of living caterpillars and butterflies, and the drawings demonstrated an aesthetical appreciation of the “incomparable beauty consisting in their [the butterflies] peculiar colors and orderly decoration” (Friedewald, 2015). Also, her drawings depict a holistic story; an all-encompassing view that includes the different stages of the metamorphosis and the specific forage-plant for each species in the same drawing. In her book *Caterpillars, Their Wondrous Transformation and Peculiar Nourishment from Flowers* from 1679, the chapters are not named for the various butterflies, but instead by the specific forage plants. The reason for this is that in her time, the names of the butterflies had not yet been officially established (Friedewald, 2015).

Picture 2: Stinging nettle and the peacock bird from “Caterpillars, Their Wondrous Transformation and Peculiar Nourishment from Flowers” (Merian, 1679, p. 50a)..

One illustration in her book on butterflies (Picture 2) shows the stinging nettle with a large black caterpillar and a pupa hanging upside down. There are two specimens of the fully formed butterfly, one in the air, showing the wings with the characteristic eyespots, and the other one sitting on the plant showing the wings' underside, which is colored dark brown or black. Besides, there are two flies in the picture because Merian found out that the common fly lays its black eggs in the caterpillar's excrement, and that the eggs develop into small white maggots from which the fly hatches. A later version of the same picture is hand colored and also depict the colors of the butterfly and plant.

Thus, Merian demonstrates a holistic and aesthetical mode of observation to answer the fundamental question *How to describe living organisms (according to their nature)?* The objective of her observations was to describe the butterflies according to their nature. To her, describing living organisms according to their nature meant to describe their life cycle and how they interacted with other living organisms. For this approach, Merian has been called the first ecologist (e.g. Etheridge, 2011). In addition, it meant to precisely depict the colors and decoration of both plants and animals as she saw them in nature.

11.1.3 Case III: An analytical and systematic mode of observation.

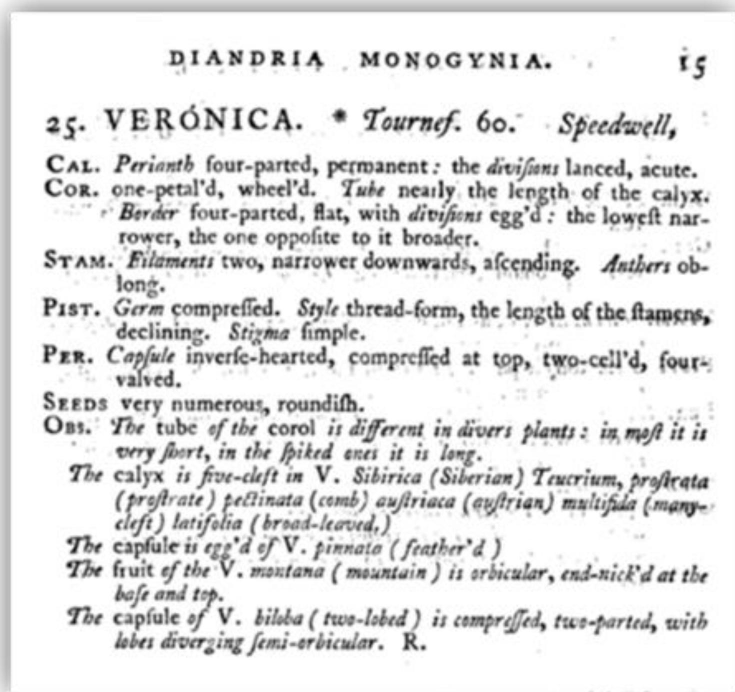
Carl von Linné was at the center of a European correspondence-network coordinating observations of nature. In this case, I will argue that the fundamental question is: *How can we systematize the diversity of living organisms?* Linné was a learned and explorative observer who combined theoretical knowledge with empirical studies. His system was based on an *analytical* and *systematic* mode of observation.

In the introduction to the first edition of *Systema Naturae* from 1735 called *Observationes*, Linné stated that "classification and name-giving will be the foundation of our science" (Engel-Ledeboer & Engel, 1964, p. 19). In the *Observationes*, he underscored that his "own authentic observations have been used in every single part, for I have well learned that very few people are lightly to be trusted, as far as observations go" (p. 19). In *Systema Naturae*, Linné presented a new hierarchical system encompassing the three kingdoms of nature in classes, orders, genera, and species. In the introduction to his next book

Genera Plantarum from 1737, he described his method of systematizing plants by flower and fruit in more detail:

> I have selected certain and real, not vague and shaky features while describing the various parts of fructification. Others often assume taste, smell, colour, magnitude (without [paying] attention to proportion). Such you will never see adduced by me, but only those four certain and firm mechanical principles: number, shape, situation, and proportion. These four attributes, together with those twenty-six letters (11) distinguish the genera so certainly from each other, that nothing more is wanted (Müller-Wille & Reeds, 2007, p. 569).

Accordingly, each genus in the *Genera Plantarum* was described by number, shape, situations, and proportion of the following parts of flower and fruit: calyx, corolla, stamen, pistil, pericarp, and seeds (Picture 3).



DIANDRIA MONOGYNIA. 15

25. VERÓNICA. * *Tournef.* 60. *Speedwell,*

CAL. *Perianth* four-parted, permanent: the *divisions* lanced, acute.
COR. one-petal'd, wheel'd. *Tube* nearly the length of the calyx. *Border* four-parted, flat, with *divisions* egg'd: the lowest narrower, the one opposite to it broader.
STAM. *Filaments* two, narrower downwards, ascending. *Anthers* oblong.
PIST. *Germ* compressed. *Style* thread-form, the length of the stamens, declining. *Stigma* simple.
PER. *Capsule* inverse-hearted, compressed at top, two-cell'd, four-valved.
SEEDS very numerous, roundish.
OBS. *The* tube *of the* corol *is different in divers plants: in most it is very short, in the spiked ones it is long.*
The calyx *is five-cleft in* V. *Sibirica (Siberian) Teucrium, prostrata (prostrate) pectinata (comb) austriaca (austrian) multifida (many-cleft) latifolia (broad-leaved.)*
The capsule *is egg'd of* V. *pinnata (feather'd)*
The fruit *of the* V. *montana (mountain) is orbicular, end-nick'd at the base and top.*
The capsule *of* V. *biloba (two-lobed) is compressed, two-parted, with lobes diverging semi-orbicular.* R.

Picture 3: Description of the Genera Veronica in Genera Plantarum (Linné, 1787, p. 15)

Thus, Linné demonstrates an analytical and systematic mode of observation to answer the fundamental question: *How can we systematize the diversity of living organisms?* The objective of his observations was to systematize nature and give names to all living organisms. To him, systematizing nature meant to classify organisms (especially plants) by characteristics that could be counted or measured in a precise way. His analytical approach included to give names to parts that he could systematize by, for instance, different parts of the flower and fruit of plants (like petals, stamens, etc.).

11.1.4 Case IV: An explanatory and synthetical mode of observation.

Alfred Russell Wallace and Charles Darwin traveled around the world and observed global patterns of dispersion of species. In this case, I will argue that the fundamental question is: *How can we explain the diversity of living organisms?* Wallace and Darwin had different background and education, but both had hands-on experience with collecting and describing a large number of species from different parts of the world. Their explanation in terms of a theory of evolution was based on an *explanatory* and *synthetical* mode of observation.

Wallace (1855) wrote: “None of the explanations attempted from the time of Linneus are now considered at all satisfactory” (p. 184). The questions that arose in the scientific communities at the time were: Where did all the species come from? Why did some species die out and others survive? Was it possible to explain the diversity of life? Could species change? Both Darwin and Wallace traveled around the world and were both inspired by the theories of Charles Lyell and Thomas Malthus. Independently of each other, they came up with the same, new explanation and decided to publish together on 1 July 1858 in the *Linnéan Society of London* (Darwin & Wallace, 1858). At that time, Darwin had already been working with his theory for 20 years, and in the book *On the origin of species* published in 1859 he broadened an elaborated the argument for a theory of evolution by means of natural selection (Darwin, 1859). In the introduction, he wrote:

> When on board H.M.S. Beagle, as naturalist, I was much struck with certain facts in the distribution of the inhabitants of South America, and in the geological relations of the present to the past inhabitants of that continent. These facts seemed to me to throw some light on the origin of species - that mystery of mysteries, as it has been called by one of our greatest philosophers. On my return home, it occurred to me, in 1837, that something might perhaps be made out on this question by patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing on it. (p. 1)

When Darwin returned to England after traveling around the world with H.M.S. Beagle, he started processing the gathered material and observations he had made on this journey. In addition, he started collecting other observations of both wild and domestic animals and plants to further develop his idea about a theory of evolution by means of natural selection. The book *On the origin of species* starts with the Chapter 1 *Variation under Domestication.* In this first chapter, Darwin discussed all the variations of domestic animals and plants that are created by humans by using a lot of examples, such as the breeding of many different types of pigeons and the cultivation of pears. In the Chapter 2 *Variation under nature*, Darwin further discussed variation in nature and in the same way as in the first chapter he refers to a lot of observations. Building on his own observations, as well as observations done by others, and theoretical knowledge, Darwin argues in the following chapters that there is a struggle of existence in nature that leads to a natural selection that favors those variants that are best adapted to their environment. The theory of evolution could explain the diversity of life on earth, the adaptions of different animals and plants to their environment, and how species could develop into new species.

On the last page of the joint publication of Darwin and Wallace (1858), Wallace conclude his essay *On the Tendency of Varieties to depart indefinitely from the Original Type* by describing the explanatory power of the theory of evolution:

> We believe we have now shown that there is a tendency in nature to the continued progression of certain classes of varieties further and further from the original type—a progression to which there appears no reason to assign any definite limits—and that the same principle which produces this result in a state of nature will also explain why domestic varieties have a tendency to revert to the original type. This progression, by minute steps, in various directions, but always checked and balanced by the necessary conditions, subject to which alone existence can be preserved, may, it is believed, be followed out so as to agree with all the phenomena presented by organized beings, their extinction and succession in past ages, and all the extraordinary modifications of form, instinct, and habits which they exhibit (Darwin & Wallace, 1858, p. 62).

Thus, Darwin and Wallace, demonstrate an explanatory and synthetical mode of observation to answer the fundamental question: *How can we explain the* *diversity of living organisms?* The objective of their observations was to explain where all the species come from by looking back into the history of life. To them, explaining the diversity of life-forms meant to synthesize many observations from around the world and find an explanation that could fit all of them.

11.2 A typology of modes of observation

Based on the four selected cases described in the previous section, I developed a typology of four modes of observation (Figure 11). My typology of modes of observations is based on different objectives with the observations. The objectives are again shaped by knowledge, prior experiences, and interest, and could be related to different contexts, such as historical or educational settings. The different modes of observtaions depend on what we find meaningful, valuable, or important in a particular context.

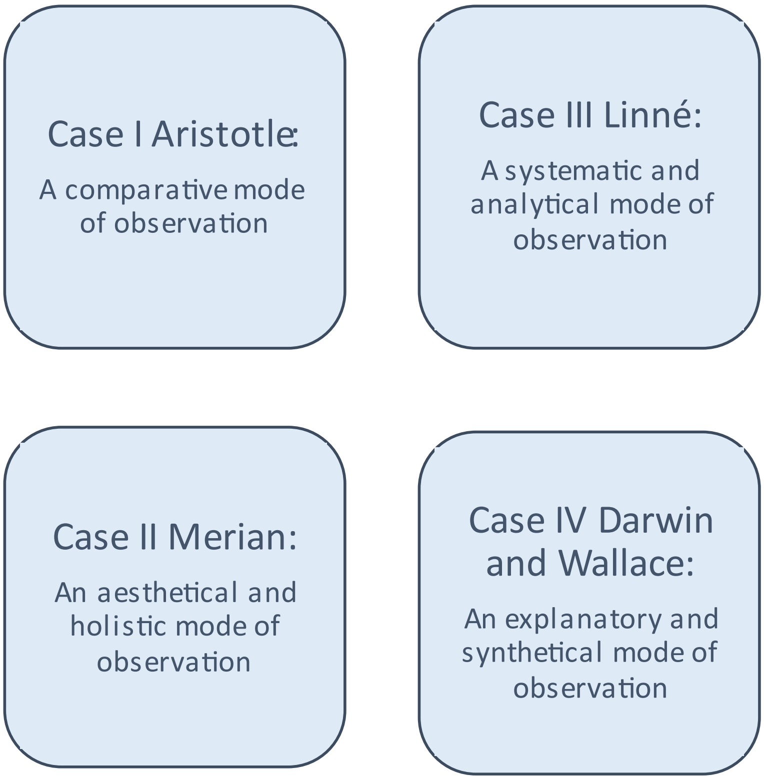


Figure 11: A typology of Modes of observation

In a *comparative mode of observation*, you try to find the essence of a certain kind of living organism by looking for similarities and differences between and within kinds, to separate it from other kinds of organisms. For instance, to find the essence of a white-tailed bumblebee (*Bombus lucorum*) you first have to compare it with other insects to find the characteristics of a bumblebee in general, and then compare different bumblebees to determine what is specific about exactly this kind. The essence of a kind can be described as the common qualities of form and function of different parts shared by all cases of this kind, and at the same time separate it from other kinds. This is what Aristotle would have called *eidos*, and which also can be understood as *unique ways of being in the world.*

To compare living organisms, you must study many specimens to find their essential characteristics and determine what is significant in their unique way of being in the world. It is a skill trained by accumulated experience with observing and comparing different organisms.

In a *holistic and aesthetical mode of observation* you seek to describe living organisms as you perceive them in nature. Living organisms grow, move, and interact, and a holistic description must incorporate these dynamics. For instance, to describe a peacock butterfly (*Aglais io*) holistically, it would not be sufficient to describe the adult stage *(imago*) of the butterfly, the species also include the pupae and the larvae which look completely different. In addition, the larvae's hostplant *stinging nettle* is an essential part of the life of this butterfly and could be incorporated in the description as well.

To be able to describe living organisms according to their nature you must be attentive. Being attentive means bringing what you observe into your field of perception and using your senses. *Aesthetics* in the classical meaning, from Greek *aisthētikos*, is exactly that; something "relating to perception by the senses"[23]. In my use of the word here, an aesthetical mode of observation refers primarily to the state of being attentive and using your senses. Being attentive is a prerequisite to describe something, but it could also be the other way around, i.e., describing something may set you in a mode of attentiveness. Further, in order to describe you must be able to express what you perceive. A description will depend on your vocabulary and/ or other individual skills of expression. A

[23] The meaning of aesthetics as something 'concerned with beauty' first arose in the 18th century in Germany. From the Online Etymology Dictionary: https://www.etymonline.com/word/aesthetic

description will also tell something about the interplay between the observer and the observed.

In a *systemic and analytical* mode of observation you seek to organize living organisms in an overall system by certain criteria for categorization. Depending on the chosen criteria, there could be many systems. For instance, to categorize a plant like the wood anemone (*Anemona nemorosa*) you will have to decide whether the criteria should be, for instance; flower color, growth-form, time of flowering (*phenology*), habitat, or number of petals or stamens. Categories could be made from all the criteria mentioned, but emphasis on one criterion or another will lead to different overall systems. This is an analytical mode of observation, where the observed is divided into parts to categorize by. To analyze means the "resolution of anything complex into simple elements" and is the opposite of synthesis[24].

To be able to systematize living organisms you must find characteristics that are categorizable, which means that they must be general and recognizable in, for instance, all plants. In addition, criteria are probably easier to categorize by if they are quantifiable.

In an *explanatory and synthetical mode of observation* you seek to find connections between different observations of living organisms and to explain these observations. For instance, explaining form and function of different parts of a woodlouse (*Oniscidea*) requires seeing connections between different observations of woodlice at different places and at different times, but also between observations of woodlice and other organisms. To answer, for instance, the question of why a woodlouse has a certain form and function, there may be causality at several layers. It is a mode of observation that synthesizes several observations into a general explanation, and once the explanation is made, it possibly affects new observations.

To be able to explain the diversity of living organisms you must make connections between many different observations and go beyond what you directly observe. It is a skill that demands an overview at an arm's length of the

[24]From the Online Etymology Dictionary: https://www.etymonline.com/search?q=analysis

phenomena and an ability to imagine the evolutionary history of different organisms.

11.3 A comparison of different modes of observation

In the previous sections of this chapter, I have argued how I have defined four fundamental questions and extracted a typology of four modes of observation from the selected historical cases (Table 7). The different modes of observation relate to what is perceived as relevant to observe, in the exploration of living nature. According to Jardine (2000) the changing perceptions of relevance in the history of science are determined by presuppositions and methodological commitments in a community (p. 78-79). According to Schickore (2020), emphasizing the questions in these explorations brings the attention to processes and contexts of knowledge generation (p. 494). In the following, I will compare the four modes of observation and discuss the presuppositions and methodological commitment in each case.

Table 7: Fundamental questions and modes of observation, in four selected cases from the history of science

Four cases from the history of science	Four fundamental questions	Four modes of observation
Case I: Aristotle (Classical Antiquity)	What is the essence of this living organism?	comparative
Case II: Merian (Renaissance)	How can we describe living organisms according to their nature?	holistic and aesthetical
Case III: Linné (Enlightenment)	How can we systematize the diversity of living organisms?	systematic and analytical
Case IV: Wallace and Darwin (Late modern period)	How can we explain the diversity of living organisms?	explanatory and synthetical

11.3.1 The case of Aristotle

Aristotle attended Plato's academy in Athens for twenty years, and Plato and Aristotle had in common the search for a foundation of knowledge. In the famous fresco "The school of Athens" painted by Raphael in 1509 -1511, Plato and Aristotle are situated in the center of the picture. By two simple gestures, of Aristotle pointing down (or maybe out) towards the world, and Plato pointing up towards the sky, Raphael manages to convey what was probably the main discussion between Aristotle and his teacher Plato. It is the discussion of how to ground our knowledge, and whether the foundation of certainty in knowledge is reason and logic, rather than experience and sensing. Since then, the same discussion has remained one of the most fundamental topics in the history of philosophy of science.

According to Plato, the foundation of knowledge are first and foremost reason and logic. In the famous *Allegory of the cave*, Plato argues that a world of ideas lies behind (or above) the world we experience with our senses, and to see the world as it really is we must "see" this world of ideas. Ideas are more real than the world we sense and experience. This implies that thinking and reasoning are the way to true knowledge, and that the senses cannot be trusted. Metaphorically, we must crawl out of the cave where we only see shadows of the real ideas on the wall, into the sunlight outside of the cave to be enlightened and to see the ideas that form the world we experience. Plato called these ideas for *eidos*, which is a Greek term that may mean form, essence, or type[25]. Thus, Plato describes the way to knowledge as a turn away from the world as we experience it towards an abstract world of ideas through reason and logic.

Aristotle, on the other hand encourages us to enter the kitchen, because divinities are present even there (see quote, p. 99). Here, it seems that to enter the kitchen may be interpreted as a metaphor for turning towards the world. Instead of elevating ourselves above the world by hesitating to enter the kitchen, we should enter and show interest in all the *things* we find there. In the same quote, Aristotle claims that every kind of animal will reveal "something natural and something beautiful" if we choose to study them. Thus, according to Aristotle, knowledge is grounded in experiences of the world in which we live and sense. Like Plato, Aristotle uses *eidos* as a notion of essence, but to Aristotle eidos is something we may reveal through empirical and comparative studies. For instance, to Aristotle, an animal's *eidos* is not an abstract form, but an essence of both form, structure, and function of the animal's parts, and how these parts serve the animal as a whole. Eidos may be seen as an animal's way of being the world. Such descriptions can only be based on actual studies of living animals in nature. With his gesture of pointing downwards (or outwards), and his turn

[25] The term comes from Proto-Hellenic *wéidos*, from Proto-Indo-European *wéydos* ("seeing, image"), from *weyd-* ("to see"), cognate to Sanskrit वेदस् (védas). From Wiktionary, the free dictionary: https://en.wiktionary.org/wiki/eidos

towards the world, Aristotle lay the foundation for all further observational practices in the exploration of living nature.

Thus, Aristotle's presupposition is that different living organisms have an innate essence (*eidos*) defined by the unique form and function of different parts, and that a species is a unique way of being in the world. Aristotle's methodological commitment is to make empirical observations based on comparison of different animals. These presuppositions and methodological commitment decide what he perceives as relevant to observe in the exploration of living nature. Aristotle's approach emphasizes comparative observational practices as a way of knowing.

11.3.2 The case of Maria Sibylla Merian

The case of Merian also demonstrates an empirical approach to explore living nature, but the fundamental question she asks is slightly different from that of Aristotle. When she wants to describe living organisms according to their nature, there are similarities with Aristotle's notion of *eidos*. Just as Aristotle, Merian does not find it satisfactory to describe a species by some abstract or general form. However, added to emphasizing empirical observations of animals in nature, she wants to include how living organism grow and change in her descriptions, and how they interact with other living organisms. Instead of asking about the essence of a species, the fundamental question in her explorations is how to describe living organisms according to their nature. To her, this means to make detailed and accurate drawings of, e.g., butterflies, based on her own observations, and her pictures seem to appeal to the senses and illustrate a story in an immediate way. To be able to describe how the butterflies grow and change, she composes pictures that include the different stages in a butterfly's life, and its interaction with the forage plant and other living organisms. Merian's pictures are composed to depict typical characteristics of a certain butterfly; however, such typical characteristics are both detailed morphological traits of the butterfly, and how it lives and interacts with other organisms.

In this case, there are some clear connections between material conditions and context, and the type of observation. Merian growing up first in her father's house with a printing press, and then in her stepfather's painting studio with a garden full of flowers and insects, gave her important experiences and let her develop certain skills. A specific incident of receiving a gift of silk-moths for her birthday also seem significant. Bringing with her all these experiences, and being a gifted artist, makes a difference to how she makes her descriptions. Merian chooses what to include, and what not to include in the picture. In addition, her skills as a painter are crucial to how she manages to depict the butterflies. Merian was not preoccupied with name-giving or systematics in particular as Linné, nor with interpretations of the observations that goes beyond her depictions as Wallace and Darwin. Still, Linnaeus and his followers named about one hundred species based on her work (Etheridge, 2016, p. 39), and several have pointed out that her plate 18 from Metamorphosis (Picture 4) in many ways portrays the struggle for survival that Darwin described more than 150 years later.

Thus, Merian's presupposition is that living organisms can be described according to their dynamic (growing, moving, transforming) and interconnected nature, and that species have specific traits in different stages and specific ways of being entangled with other species. The methodological commitment is to make observations to provide accurate and holistic descriptions of living organisms as we see them. These presuppositions and the methodological commitment decide what she perceives as being relevant to observe in the exploration of living nature. Merian's approach emphasizes holistic and aesthetical observational practices as a way of knowing.

Picture 4: Plate 18 from "Dissertation in Insect Generations and Metamorphosis in Surinam", second edition), 1719. In the National Museum of Women in the Arts.

11.3.3 The case of Carl von Linné

Linné demonstrates yet another approach to exploring living nature and he underscores that his "own authentic observations have been used in every single part" (Engel-Ledeboer & Engel, 1964, p. 91). The fundamental question in Linné's explorations is how to systematize living organisms. Linné is convinced that there is an innate order in nature and he thinks nature is a book we must learn to read, and "the system of nature was to him the working plan underlying Creation" (Engel-Ledeboer & Engel, 1964, p. 7).

This way of thinking is a prevailing idea in the period of enlightenment and influenced by the investigative method described in *Novum Organum Scientiarum* (1620) by Francis Bacon. After the reformation and at the beginning of modern science, nature became a book already written from beginning to end that should be read literally, and according to Ingold (2013), by reference to Harrison (1998):

> In a science constructed in the spirit of Bacon (…) to know is no longer to join *with* the world in performance but to be informed *by* what is already set down there (p. 743).

In this spirit, the scientists set out "to discover, through some process of decoding or deciphering, what exist already in fact", and the world become "a repository of data that, in themselves, afford no guidance on what should be done with them. (…) Thenceforth, wisdom took second place to information." (p. 743). With classification, living organisms become discrete and bounded entities. When these entities are ordered and arranged, we seem to decode the information that is already there in nature, and when the species are named, we seem to know them.

Although Linné thinks that there is a natural system to be revealed in nature, he starts his investigations by establishing what he calls an artificial system. His justification for making an artificial system is pragmatic; until we know the natural system, we must start by making a system that can be used to systematize all the already existing knowledge about living organisms. In the introduction to the first edition of *Genera Plantarum* he writes:

> And it is not possible to hope that our age will be able to see any natural system, nor perhaps will posterity. Nevertheless, we are striving to know

> the plants; so meanwhile artificial and substitute classes have to be assumed (Linné in Müller-Wille & Reeds, 2007, p. 567).

Linné argues that quantitative properties in flowers and fruits are sufficient to make a system of plants, not that these properties are essential. Thus, he analyzes flower and fruit in plants. He divides the flower and fruit into generic parts and give names to these parts. From this he makes an artificial system of classes of plants, called Linné's sexual system (Linné, 1787, p. xxvii). At the same time, he performs empirical studies of specimens of plants in nature, and in his garden and herbarium, and sort the plants he studies into different genera of plants and strive to establish what he perceives as the natural species and genera. With reference to another botanist Boerhaave, he writes:

> Teachers are to proceed from generalities to particulars, while explaining discoveries; while inventors, to the contrary, have to pass from particulars to generalities (Linné in Müller-Wille & Reeds, 2007, p. 565).

Linné seem to recognize both deductive and inductive methods to get knowledge of plants. However, he firmly believes that there is a system to be found in nature.

Thus, Linné's presuppostions is that there is a natural system to be revealed in nature, and that species are discrete and bounded entities with fixed properties. The methodological commitment is to make observation based on quantitative analyzes. These presuppositions and methodological commitment decide what he perceives as relevant to observe in the exploration of ling nature. Linné's approach emphasizes systematic and analytical observational practices as a way of knowing.

11.3.4 The case of Wallace and Darwin

The case of Wallace and Darwin, like the case of Linné, demonstrate both inductive and deductive approaches to explore and get knowledge about living nature. Wallace and Darwin are led to the questions about the origin of species by their own observations, but also by observations done by others and theoretical knowledge like, for instance, the work of Lyell (1835). The question about the origin of species makes them look for connections between observations done at different places, and at different times. When the idea of a theory of evolution is formulated, they both start to look for observations that can be explained by such a theory.

The explanatory power of the theory of evolution is supported by references to many different examples, both in the essay written by Wallace in the joint publication by Darwin and Wallace (1858), and especially in Darwin's book *The Origin of Species*. Darwin's first chapter *Variation under Domestication* is based on studies and conversations with animal breeders and farmers. Darwin describes familiar examples and shows that human selection influences the development of cultivated plants and livestock in certain directions, and he summarize these observations:

> We cannot suppose that all breeds were suddenly produced as perfect and as useful as we now see them; indeed, in many cases we know that this has not been their history. The key is man's power of accumulative selection: nature give successive variations; man adds them up in certain direction useful to him (Darwin, 1859, p. 30).

In another instant, Darwin demonstrates a more deductive approach when he refers to an experiment to investigate his idea about the struggle for survival and natural selection:

> Seedlings, also, are destroyed in vast numbers by various enemies; for instance, on a piece of ground three feet long and two wide, dug and cleared, and where there could be no choking from other plants, I marked all the seedlings of our native weeds as they came up, and out of the 357 no less than 295 were destroyed, chiefly by slugs and insects (Darwin, 1859, p. 67).

The two quotes above are only two examples out of many of how Darwin thoroughly build his argument for a theory of evolution in *The Origin of species*. With his examples and arguments, he demonstrates how he arrives at this explanation and how the explanation applies to specific examples.

Thus, the case of Wallace and Darwin is both a process of going from specific observations of nature to a generalized explanation that go beyond the singular observations, and a process of going from a general theory to explain specific examples and conclusions. Darwin and Wallace's presupposition is that living organisms are interconnected and part of a long history of evolution, and that species can change and become new species. Their methodological commitment is to connect observations of living organisms from around the world and explain all the observations with a general theory. These presuppositions and methodological commitment decide what they perceive as relevant to observe in the exploration of living nature. Darwin and Wallace's approach emphasizes explanatory and synthetical observational practices as a way of knowing.

11.3.5 Four ways of knowing living nature

The four cases demonstrate the connection between material conditions (time, context), mode of observation, and what has historically been perceived as being relevant to observe in the exploration of living nature. The central actor(s) in each case pose(s) a different fundamental question that are influenced by the time they live, and the different conditions and possibilities in their lives. The changing questions in the history of science demonstrate different perceptions of what has seen as being relevant to explore (Jardine, 2000, p. 77). In all four cases, making empirical observations of living organisms in nature is part of the methodological commitment, however, the way in which these observations are made produce different knowledge. Among other things, the presuppositions made about species in each case reflect a plurality of species concept that may serve different purposes (Agapow et al., 2004; Reydon & Kunz, 2019). Both cases of Aristotle and Linné, reflect an essentialist species concept where each species is characterized by an unchanging essence and typical traits (e.g. Mayr, 1982, pp. 256-260). Merian on her side, does not define species, instead she composes pictures that portray typical features of specific butterflies, including both morphological traits and how the specific butterfly transform in different stages. With Wallace and Darwin's theory of evolution, species can no longer be defined by an essence, or by typical traits, because with this theory species may change and become new species. Darwin recognizes what has later been called the grouping and ranking problem of species (referred to in Chapter 2) that refers to the questions: On what basis should organisms be grouped as species? And on what basis should such groups be ranked as species? (Reydon & Kunz, 2019). As such, the theory of evolution represents a breach with the former understanding of species as fixed entities, and may also challenge the traditional view of natural kinds among most people and of species as fixed entities that exist in nature (Reydon, 2013).

Table 8: An overview of the fundamental question, presuppositions, methodological commitment, and observational practices in each case.

Case	Questions	Presuppositions	Methodological commitments	Observational practices as ways of knowing (epistemologies)
Aristotle	What is the essence (*eidos*) of this living organism?	Living organisms have an innate essence (eidos) defined by the unique form and function of different parts. Species have essential characters and are unique ways of being in the world.	To make empirical observations based on comparison of different animals on several levels.	Comparative observation to find essences.
Merian	How can we describe living organisms according to nature?	Living organisms can be described according to their dynamic and interconnected nature. Species are dynamic entities with specific traits in different stages, and with specific ways of being entangled with other species.	To make observations to provide accurate and holistic descriptions of living organisms.	Holistic and aesthetical observations to make natural descriptions.
Linné	How can we systematize the diversity of living organisms?	There is a natural system to be revealed in nature. Species are discrete and bounded entities with fixed properties.	To make observation based on quantitative analyzes.	Systematic and analytical observations to make systems of classification.
Darwin and Wallace	How can we explain the diversity of living organisms?	Living organisms have evolved and are part of a long history of evolution. Species are not fixed entities and may instead be described as single linages of common descent.	To make an explanation based on many observations from around the world	Explanatory and synthetical observation to explain

The fundamental questions that are asked relate to the presuppositions and methodological commitments that are made in each case, and lead to different understanding of what is perceived as relevant observations. These observational practices can be seen as different ways of knowing, or different epistemologies (Table 8).

11.4 Design of teaching cases

The objective of the teaching cases is to create opportunities for both teachers and students to experience phenomena in living nature through different observational practices demonstrated by the selected historical cases. The four teaching cases were presented in a booklet with texts, pictures, and exercises, and told as four stories about the five central actors. In each story, based on an analysis of the historical sources, I emphasize the fundamental question posed by the central actor(s), describe the observational practices each person applied to answer their question, and what kind of answers they found.

Building on the previous sections in this chapter, I will now answer research question 1:

> How might cases from the history of science be designed to strengthen teachers' and students' observational practices and knowledge about living nature?

I will demonstrate a didactical analysis based on Klafki (2006) to describe how historical teaching cases were designed and prepared for teaching in this project, and summarize the analysis in a general structure for designing teaching cases. At the end of this section there are four QR-codes that link to the four original pdf. documents, one for each case, that were written for the students and used in the classroom.

11.4.1 Preparing historical cases for teaching

Building on Wagenschein's didactical principles, Klafki (2006) summarizes the purpose and task of preparing teaching in his *Didaktik analysis*, as follows: "Preparation is intended as the design of one or several opportunities for children to make fruitful encounters with certain contents of education" (p. 116), and in this preparation "the task is to elucidate which aspects of the content contribute to *Bildung*" (p. 117). Thus, to prepare for teaching is not simply a question of method, the teacher must start with the specific educational content (*Bildungsinhalte*) and analyze how this content might contribute to the process of *Bildung*.

In my project, the phenomenon of observing living nature define the educational content. To prepare teaching cases from the history of science to explore living nature, I find the questions Klafki asks in his *didaktik analysis* useful (p. 123-129). I will discuss each of the question to describe how I have prepared the teaching cases for the students.

1. *What wider and general sense or reality does this content exemplify and open up to the learner?*

To the students the phenomenon of observing living nature may open up to both a wider understanding of what science is, and to a reality of engaging with other living beings in nature. How students observe and interact with other living beings goes beyond science education, and in the Norwegian school, it is also part of an education for sustainability. In an education for sustainability the fundamental issue is how we design for teaching that prepare students to participate as democratic citizens in a sustainable society. How the students learn to pay attention to living nature may be crucial to how students experience and understand sustainability.

2. *What is the significance of this content to the students – now and in the future?*

The phenomenon of observing living nature already has a significance to the students through their different experiences in nature, for instance, by playing outdoors, going on walks with their parents, picking blueberries in the woods, collecting earthworms in kindergarten, smelling flowers, feeding birds, or maybe eating apples in their grandmother's garden. Although there seem to be a loss of experiences with nature (c.f. Kahn & Thea, 2017), all the students have some kind of experience with observing living nature. However, their experiences may be very varied, many or few, and what they perceive as significant in these experiences may be manifold.

To prepare the teaching I use the students' familiarity with the topic and reflect on in which ways the students already have access to the topic, and in what ways the topic may be unfamiliar to them. The questions I ask are: How can I make a certain phenomenon richer to the students? How can I design for “opportunities for children to make fruitful encounters” (Klafki, 2006, p. 116) with the phenomenon? How can I design experiences that open up to new experiences? (cf. Dewey).

3. *How is the content structured?*

The phenomenon of observing living nature refers to practices for exploring and a specific content in terms all the *things* in living nature. The students may develop their observational practices as a general competence regardless of the content (as in formal *Bildung*), and they may develop knowledge of the *things* in living nature without practicing observation (as in material *Bildung*). However, the goal here is to prepare teaching that contributes to both the formal and material as in categorical *Bildung* (Klafki, 2006). In the phenomenon of observing living nature the content and the methods for exploring are closely connected, the *things* students observe may influence how they observe, and the way in which they observe may influence what *things* are brought to the foreground. To prepare the teaching, based on my reflections on questions 1 and 2 above, I must consider which elements to include in teaching, how these elements are related, how they make a meaningful whole, what the wider context is, and what elements might be difficult for the students (Klafki, 2006, pp. 126-127). The questions I ask are both: What are the fundamental elements in different modes of observation? And what *things* in living nature are essential in this exploration?

The four teaching cases describe different ways to get knowledge of living nature through observation (Table 8). Based on the developed typology of modes of observation, the main elements in these observational practices are: 1. comparison, 2. holistic and aesthetical attention, 3. analysis and systematization, and 4. synthesis and making explanations. The elements are complementary to each other, although they might not be exhaustive to all observational practices.

Using a phenomenological approach, I aim to prepare teaching that stays close to the phenomena in living nature, and that connect the educational content and the students’ lived experience (Roth, 2015; Østergaard, 2015). Thus, each case investigates phenomena in living nature that each of the central actors perceived as relevant to observe, but that are familiar to the students as well, and possible for them to observe. Thus, the first case demonstrates the comparison of common groups of insects, the second, descriptions of butterflies and their life cycles, the third, systematization of some of the common families of flowering plants, and the fourth, the explanation of diversity in insects' legs and birds' beaks.

4. *What are the special cases or phenomena that can make the content stimulating, accessible, or vivid to the children?*

To make the content vivid and accessible to the students, I tell four stories about five central actors in the history of science. In each story, the students get to know the central actor(s), under what conditions they lived and what inspired them to explore living nature. This is in line with contextualizing science (Tala & Vesterinen, 2015). I base each story around the fundamental questions and observational practices, that were the result of the analysis of the selected historical cases, described in the first section of this chapter.

Inspired by Cavicchi (2015) and her description of historical actors as "virtual members in the classroom" (p. 186), the purpose of designing the teaching cases is to inspire the students and the teachers to make their own explorations. The historical virtual members in the classroom, like Aristotle, Merian, Linné, Wallace and Darwin in this project, are guides to the exploration, and someone to communicate and discuss with along the way. In the process of exploring living nature, the students get the opportunity to practice the skill of observation and aquire knowledge of the phenomena in living nature.

Thus, to strengthen teachers' and students' observational practices and knowledge about living nature, each of the teaching cases is designed by the structure described in Table 9. They all start with a prologue that introduces the historical time period and describe the context and what was perceived as the relevant questions to explore in this time period. Then I go on to describe the more specific context, time, and place that each of the central actors lived under, and what they found relevant to explore in living nature. I emphasize the personal and context-specific details that inspired them to start their investigations to make the story vivid and accessible to students. Furthermore, I focus on a main fundamental question that the central actor(s) seeks to answer to make clear the intentions of the exploration. Then follow accurate and exemplified descriptions of the observational practices applied by each the central actors to answer the question. Each case also has tasks for the students to engage in the same kind of observational practice. The story ends with a description of the resolution and answer to the fundamental question, followed by an epilogue that points forward and encourages the students to do further explorations in nature on their own. I have generated QR-codes that link to the four original booklets written for the students (Table 10).

Table 9: Structure of the teaching cases from the history of science.

	Design of teaching cases
1.	A prologue that introduces the historical time-period
2.	Description of the more specific context, time, and place that each of the central actor lived under, and what they perceived as relevant to explore in living nature.
3.	Emphasize on a main fundamental question in each case that the central actor(s) seeks to answer.
4.	Accurate and exemplified descriptions of the practices each the central actors applied to answer the question. Tasks for the students to engage in the same kind of practices.
5.	Description of the resolution and answer to the fundamental question.
6.	An epilogue that points forward and encourage the students to do further explorations in nature.

Table 10: QR-codes that link to each of the four original booklets written for the students.

Case I:	**Case II:**	**Case III:**	**Case IV:**

12 Modes of observation in teaching and learning

> … and then you see something and then you think that there is nothing more, and then you look once more, and you see more (Sebastian, 5th grade student).
>
> … and then when you come back, you see something else (Lisa, teacher).

In this chapter, I will present the results of my phenomenological analysis of the interviews with teachers and students in phases two and three of the case study. The interviews were analyzed in the steps described in Chapter 10, resulting in several themes that I will present and discuss in this chapter.

The aim is to answer the research questions belonging to phases two and three:

> How do teachers experience the practice of observing living nature in the context of teaching and learning science in primary school?
>
> How do 5th grade students experience different modes of observing living nature demonstrated through four cases from the history of science?

I will proceed as follows: In the first section I will present and discuss the themes that emerged from the interviews with the teachers in Phase 2. In the next section. I will present and discuss the themes that emerged from the interviews with the students in Phase 3. In the third section, I will describe and discuss the teachers' experiences with applying the different modes of observation in their teaching in Phase 3. In the last section, I will discuss these themes together to answer the research questions above.

12.1 Teachers' experiences in Phase 2

Four main themes emerged from the interviews with the teachers in Phase 2 and the subsequent analysis of the transcriptions. I will present and discuss the four themes (Table 11). The themes describe essential aspects of the teachers' experiences with *observing living nature* in the context of teaching and learning science in primary school, and the four themes will help point to the meaning of these experiences. Descriptions will include examples from the interviews and my comments and interpretations.

Table 11: Themes that describe essential aspects of the teachers' experiences with observing living nature.

Themes from the interviews with the teachers
Theme 1: "You do not see any facial expressions in nature."
Theme 2: "You have to know what to look for, so you don't just look for anything that doesn't matter."
Theme 3: "Being a teacher is to explain."
Theme 4: "You must know enough to see what you see."

12.1.1 Theme 1: *You do not see any facial expressions in nature*

There are several statements from the interviews with the teachers that express different aspects of what the things we observe in living nature are, both as something that may be hard to grasp and as something concrete.

In his interview, Thomas has an intriguing statement about how things in nature may be hard to grasp. He talks about how he uses pictures of children in recognizable situations in his social-sciences classes to let the students observe and interpret facial expressions and body language. He goes on saying:

> After all, it [interpreting facial expressions] is hard to do when one is observing in nature (…) because one is much less used to it, you do not see any facial expressions … or bowed head or …[a]

Thomas says that you do not see any facial expressions or other type of body language (such as a bowed head) when observing nature. In other words, nature lacks such human-like features. This lack of recognizable "facial expressions" in nature seems essential to me, but its meaning is ambiguous. It may point to a meaning that we as humans have a diminished ability to observe and recognize other, or non-human, organisms that make our observations of them less nuanced, or even less emphatic. Another meaning might be that nature has other evocative features that we are less used to, or have lost the ability to sense, meaning that there is not necessarily a lack of "facial expression" in nature, but we need to get used to observing and interpreting those expressions.

Another related essential aspect of living nature recurs in all interviews. When the teachers were asked what a species is, they struggled to formulate an answer. They felt that they knew what it was but found it hard to express in words. When asked about how to distinguish species in nature, Tom answered:

> There are *things* that can be difficult [to distinguish], but you try to see if they look the same (…) If you observe two ducks that look different, you think they must be different species, but then they are male and female. (…) I do not know, a species .... you have learned some species after all (…) If they look the same, maybe it's the same species, then you suddenly find out that these oak trees are not the same species, because one is summer oak and one is winter oak. (…) So, then the question is how small the differences can be for them to be two different species. I know there are some mushrooms that I think maybe should be different species, because I have seen two very different *blusher mushrooms*, there is one that is pinker and the hat falls off, and one that is darker and the hat is more firm. After all, they are two completely different *things*, classified as the same species. Should they have been two different species? I don't know, but who's going to decide?[b]

Tom's reasoning reflects his own experiences with trying to distinguish between species in nature. He uses three concrete examples: ducks, oak trees, and blusher mushrooms. The first is an example of what looks very different to begin with, but actually is the same species. The second is an example of two things that look similar to one another to begin with, but actually are different species. The third is an example where knowing the subtle differences between species may be vitally important, at least if you want to eat the mushroom. A blusher mushroom (*Amanita rubescens*) is an edible mushroom, but it may be mistaken for the rather toxic panther cap (*Amanita pantherine)* if you do not recognize the difference between them. The ability to observe and recognize other organisms seems to depend on Tom's own lived experience and what is significant to him. Tom's statement reflects an experience that distinguishing between species is not straightforward, and he also poses the question of "who is going to decide". I think this experience points to a meaning that a species is not necessarily a given entity, but rather that its definition is a question of what matters in an observation and who decides what matters. The statement might even suggest that the perception of species as something given tends to be less obvious the more species you know.

In the interview with Lisa, she describes how vast and diverse living nature appears to her when asked about what stayed with her with after the course:

> What stayed with me is that it is like nature (…), it is so big that we cannot imagine it. It's kind of endless. A bit like when you dive, you constantly see something new, and then you see something, and then you see something new. You just see right in front of you, and then when you come back you see something else. (…) that stays with me. There is always something more behind what we see.[c]

This statement belongs to a recurrent topic in the interview with Lisa that living nature reveals new things when you start to look carefully. Her statement above describes an experience of living nature as something that is not fixed and that invites to endless discoveries. Like Tom, she uses her own experiences as an example to express what she means. In this case, her experiences with diving in the ocean and the feeling that “you constantly see something new” and that “you come back [to the same spot] and see something else”, seems to become a metaphor for how nature constantly may reveal new layers and depths in perceiving. Again, the statement points towards a meaning that how you perceive nature depends on your own lived experience, and how one experience lead towards a new experience and thereby motivates further explorations (cf. Dewey).

On the other hand, both John and Thomas express different aspects of the things in living nature and they see them as something concrete and actual. For instance, when I asked about the meaning of observing living nature in learning, John answered:

> So, it is to get to the basis in a way, that it is not just their [the students] own opinions and views, but that they go in and look at it [nature] quite concrete and what it actually is.[d]

John says that observation gives the students the opportunity to study nature in a concrete way to see “what it actually is”. The meaning may be ambiguous, but it seems to me that John, in this case, perceives nature as something concrete that gives access to what actually is there. He says that through observing living nature the students “get to the basis”, and that “it is not just their own opinions and views”. The word ‘just’ here indicates that by observing nature the students no longer only have their own views, they have access to something more. John does not elaborate what he means, but his statement has ontological implication of there being a world that give access to things that exists.

These different aspects of observing living nature expressed by the teachers point to a meaning that living nature is vast, it is growing and dynamic, and the boundaries between the things we observe are not fixed. In addition, as humans, living organisms that are other than human may not be immediately recognizable to us. It means that living nature may be hard to grasp. Still, living nature is also perceived as both accessible and concrete, and it is something that invites us to explore in endlessly many ways. Thus, the things the teachers observe in living nature are perceived as being concrete, however these living things are both dynamic and a result of lived experiences.

12.1.2 Theme 2: ***You have to know what to look for, so you don't just look for anything that doesn't matter***

This theme emerges from the teachers’ discussions of what it means to practice the skill of observation, and whether this skill includes knowing what to look for or not.

Knowing what to look for

In my interviews with the teachers, the meaning that students need to know what to look for when observing living nature, is recurringly expressed and discussed when the teachers talk about different aspects of practicing the skill of observation with their students. When Lisa is asked to elaborate on the meaning of teaching the students what to look, she says: “You have to know what to look for, so you don't just look for anything that doesn't matter”.[e] She further use the example of the puzzle-book series for children called *Where’s Wally?* The students need to practice looking for the boy with the sweater with red stripes, or otherwise they would just look for anything else, she says. She continues: “The same is true in science class [when observing living nature], you [as a teacher] have to give them [the students] some clues". The above statements imply that some things matter more than others in observation. In practicing the skill of observation, the question of what is significant in the observation and to whom, seems essential.

In the interview with Thomas, this aspect is further developed. Thomas claims that the students need to know what to look for but adds that students should discuss and agree on criteria beforehand. In his first log, Thomas writes that there may be different opinions about what is relevant and irrelevant in observation, and when asked to elaborate on this, he says:

> If you are going to observe something then it is okay to agree in advance what to look for, and then it is important (…) that the students gain ownership to it, that they have helped to decide what to look for.[f]

According to Thomas, it is important that the students "have helped to decide what to look for". An important part of practicing observation of living nature seems to be for the students to discuss what the criteria should be and to be able to make them their own. This points to a meaning that the students should not only know what to look for in practicing observation, but also get the chance to make the criteria meaningful and significant to themselves.

An open way of observing

In contrast to an observation where you know what to look for, the teachers also gathered experience with an open way of observing in the woods, during the course. When Tom was asked, in the beginning of the interview, about what methods of observing living nature seemed valuable to him as a teacher, he answered:

> Tom: When we just sat quietly in nature listening and watching things, it felt too hippie for my taste (…)
> Me: You have to explain what you mean by that
> Tom: It is a little hard to describe, but it is a bit like…, what to call it, ... it is kind of sit and listen to nature, …spiritually, I don't know. Of course, it is a way to observe too, and as you pointed out, (…) you notice things in a

> new way, and you get to compare two different biotopes ... But I like it more concrete (…).[g]

In the interview, he goes on saying that to let the students observe in an open way might still be a way of teaching that he could use to involve more students, but he does not find it very scientific. He further explains that he prefers, for instance, to look for specific characteristics to classify insects. However, he interrupts his own reasoning and says: "Then there is the argument that if you are going to investigate something new, then you don't know what to look for, because then you have to look at things in a new way."[h] Here, he points to the important aspect that we sometimes do not know what to look for, especially when exploring something new.

Tom expresses some ambiguity and tension between observation as knowing what to look for, like specific characteristics to classify insects, and observing in an open way, like sitting quietly in nature. He does not like open observation and finds it less scientific, still he admits that it makes "you notice things in a new way". This points to a real ambiguity with practicing observation of living nature. It might suggest that once the criteria are given and some things are defined as being more significant than others, both students and teachers are missing out of other observations that might have been significant as well. Practicing how to investigate something new in an open way could be an important part of practicing observation, also as part of a scientific observational practice.

The interaction of skills in observation

Another recurrent expression from all the interviews, is that it is hard to distinguish between the skills of describing, systematizing, and explaining, as part of observing living nature. These skills relate to the four historical cases that were presented in the course. In the interviews all the teachers were asked to elaborate on prior experiences with practicing each of these skills with their students.

One example of how teachers find it hard to distinguish between the skills of describing and explaining is demonstrated when Lisa talks about her experience with practicing how to explain observations of living nature. Lisa describes an exercise where students sit back-to-back. One of the students holds a picture of an animal or a plant and describes it, and the other one is trying to guess what it is. Lisa says:

> Then you explain, it has hips like this, or this animal has feelers. Then the other one must guess what animal it is, if he/she manages to figure it out ... But it is not really an explanation, it becomes a description of what it looks like. But it could have been an explanation if one explains the properties ... Then it's not simply a description, ... it catches fish with its hands, (…) it sleeps in winter in the den. That is, after all, an explanation, not just a description.[i]

Here Lisa discusses with herself the difference between explaining and describing. While talking, she realizes that the exercise she describes is not a practice of how to explain, but rather how to describe what something looks like. However, according to Lisa, if the student in addition starts to “explain the properties” of the animal, like “it catches fish with its hands”, it will be more of a type of explanation. The statement suggests that an explanation goes further than a description, and even beyond what you see directly. It seems to me that to be aware of the differences between describing and explaining may be essential in practicing observation.

Several statements from the interviews express how observation may be affected by and dependent on the skills of describing, systematizing, and explaining what you see. For instance, the opinion that describing what you see changes the observation is recurring and expressed in different ways in all interviews. One fundamental aspect is that students need to learn concepts to describe what they see, according to the teachers. However, three of the interviewed teachers also highlight the importance of describing what you see by drawing, and how this might change the observation. Victoria reflects on how she (in the future) would like to practice description with her students as part of observing living nature. She says that students could “make a book for example, …to describe plants or an insect, and it would be nice [for them] to be able to make drawings, at least I liked that.”.[j] Victoria elaborates on her own positive experiences with drawing in school and says that what she drew became clearer to her, and that she liked it very much. Concerning what it may mean for the students to express themselves through drawing when learning about living nature, Victoria says:

> There are many students that might have liked it [to describe plants or animals] even better, many who think it is fun to create things and draw and are very motivated when something looks nice (…) It gives a slightly different entrance to the natural sciences. It is a way to learn. (…) Most children are very visual. You remember better if you make something or draw something yourself. You remember maybe colors better than the number of claws, for example (…) Nature is beautiful, one gets a slightly different relationship with nature even.[k]

To Victoria, drawing is a way to learn, and in her experience, children are visual and remember better when they draw or make something. Children might even get a different relationship with nature. Other examples of how drawing change the observation, are described by Thomas and Tom. Thomas says, describing his own experience with drawing an insect, "you get a closer look at it when you use your hand"[l]. Tom emphasizes that his students have "to look more closely at what things really look like"[m] when drawing. In other words, it seems that drawing forced both the teacher and the students to observe differently: they saw the plant or animal they drew more clearly, or they got a closer look. All these statements imply that drawing makes both the teacher and the students involve and connect more senses in observing and even connect with what they observe in a different way.

Also, Tom emphasizes the importance of using several senses when observing. I ask him to elaborate on this statement from his notes: "I believe that if you get to use several senses in the learning phase, you remember things better, and primary school students find it more exciting". He answers:

> When you observe, you use several senses. You tend to only think of the sight when you observe, observation with the eyes, but you can observe with the ears, nose, mouth as well (…). Today, when we collected leaves, even though we were collecting deciduous trees, we found sorrel, and then they [the students] got to taste sorrel (…) That makes things a bit exciting. So, it's connected to observing and using more senses. But to recognize a tree we basically only need a sense; one only needs the eyes, right? But if there are some trees that I know, such as elm, then you feel the elm leaf, (…) then you know it (…).[n]

According to Tom, using several senses, like tasting sour sorrel and touching the sandpaper-like elm-leaf, the students both remember the observation better and find it more exciting.

The interaction between observing and explaining, is also recurrent in several interviews and suggests that the order in which these activities are performed may be essential. Whether the teacher explains before observing, or lets students observe, ask questions, and then search for explanations, may make a difference. Related to this, in the beginning of the interview Thomas expresses the importance of observing as part of learning about living nature:

> I think that observation may create wonder and fascination for life in a way (…) In wonder there are questions, by observing one can jointly come up with questions that are exciting to work on. However, it is difficult to make good questions (…) Observation is important in that way I think.[o]

Thomas says that observation may create wonder and lead to good questions to work on, which suggests that observation should be prior to questions and explanations.

All these statements by the teachers implies that practicing the skill of observation is complex, and that it brings forward a tension between knowing what to look for and to observing in an open way to see something new. To practice observation, students might need to engage in a discussion about what is significant in an observation. The interaction of skills suggest that students should be given the opportunity to describe their observations in different ways, and that the order of explaining and observing may be essential to consider by the teacher. In the context of teaching and learning this might imply; that letting students observe and create their own questions and criteria, may be a better way to practice observation than telling them what to look for.

12.1.3 Theme 3: *Being a teacher is to explain*

This theme emerges from the teachers' discussions of what it means to be a teacher and their role as teachers when students are practicing observation, and whether they should walk along with or lead their students' explorations.

A recurrent statement in the interviews is that to teach is to explain. In the interview Lisa says about her role as teacher:

> You explain all the time, being a teacher is to explain. (…) you explain why things are as they are, why you must conjugate a verb, you must explain the world, everything must be explained.[p]

In one way or another, all the teachers express that explaining is a large part of their teaching. When asked about how they explain observations with their students they all have concrete examples. For instance, to John and Victoria doing experiments with students in a science class is about explaining what happens. John says: “Much of what we do when we have experiments in physics... is about explaining (…)there's no doubt about that.”[q] He goes on describing an experiment he has done with his students with a water-rocket, and how they used physics to explain how it works and “how things are”.[r] Similarly, Victoria describes an experiment they did where they connected steel-wool to a battery to see how it starts to glow: “We do experiments and then we try to explain what happens.”[s]

These statements are unclear about whether the teacher or the students are supposed to explain the observations. Tom on the other hand says it more clearly: “I cannot expect them [the students] to explain why or how it has become like this or that. To explain (…), to link it [the experiment] to some scientific principles or concepts or theories, I find useful [when teaching].” And later he adds: “I like to explain things, that's what teaching is in a way, communicate and explain it in a way that students understand it.”[t] Both Tom and Lisa literally say that to teach is to explain. Lisa says, as a teacher you must explain the world to the students. According to these statements, it seems to me that explaining is essential to the teachers in their role as teachers. It seems that they teach their students by explaining how things work and how things are.

However, a recurrent statement in the interviews is also that explanations may stop students’ explorations. For instance, Victoria reflects on her experience with doing experiments with the students, and says that “maybe one should have waited even longer with the explanation, spend more time on the actual process of observation and description…?” When asked why this could be important, she says: “It is a large part of science (…), the process itself ..., but there is also a lot of learning in it, the motivation to find the explanation.”[u] The statement seems to imply that when given the explanation (to fast) the students are likely to be less motivated to do their own explorations.

These different statements suggest that teachers see teaching as a way of explaining the world to the students. Still, they also see that given explanations may stop students' own exploration. I think the statements leave the question of the teachers' role in observation open. For the teachers, the crucial question might be what the role of the teacher is if it is not about explaining or telling.

12.1.4 Theme 4: *You must know enough to see what you see*

This theme emerges from the teachers' descriptions and discussions of observations as part of a scientific practice, and whether it is a practice of attention or intention.

Different ways of exploring living nature were exemplified through the four cases from the history of science in the continuing education course for the teachers. In these cases, observation is an essential part of scientific practice. When asked about what a scientific practice is, Thomas answers:

> I just have to think (…) what is not scientific practice ... That is to say that you see something you do not see (…) Scientific practice means you must know enough to see what you see. It is important, then, to practice not seeing something that you do not see.[v]

According to this statement, to observe scientifically "you must know enough to see what you see". This definition is ambiguous, but it suggests that (scientific) knowledge enables you to recognize what you see. Further, to observe scientifically you must "practice not seeing something that you do not see". Here, the meaning is even more unclear, if you have to practice not seeing something, it might suggest that there are some things you are not supposed to see, or that some things are not really there. This implies that a scientific observation is deductive and that you need knowledge to see the real or essential things in our world, or the laws of nature behind what we are able to perceive directly.

Lisa describes another aspect of scientific observation. After learning about Merian and her way of observing, Lisa wrote in her log that "nature must be experienced with all senses". In the interview she is asked to elaborate on this, related to describing nature, and she answers:

> You do not always know what you are looking for (…) you just describe it, and it will come to you eventually. Like them [the scientists], they did

> not always know which animal or plant, or the kinship between animals, they found out eventually (…) They did not know it, they just described and described and then they compared, and then, (…) here it was something similar (…)[w]

The statement by Thomas seems to describe a deductive and intentional way of observing scientifically, where "you must know enough to see what you see", while the statement by Lisa seems to describe more of an inductive and attentional way of observing scientifically. On the one hand, a scientific practice presupposes knowledge and theories that can be used to observe and interpret what you observe in certain ways. On the other hand, the history of science shows the importance of continuing to observe and describe, without knowing exactly what to look for, to be able to create new scientific knowledge.

12.1.5 An overview of findings

In the previous sections, I have presented and discussed four themes that describe essential aspects of how the five teachers in this project experience the phenomenon of observing living nature in the context of primary school science education (cf. research question 2). I would like to highlight the following findings:

Theme 1: ***You do not see any facial expressions in nature***

- The teachers express in different ways how they sometimes struggle to recognize and delineate the *things* in living nature, and one of the teachers describe a lack of recognizable "facial expressions" in nature. Their descriptions and perceptions of the things in living nature demonstrate their lived experiences with observing living nature.
- One of the teachers experiences that living nature invites to endless discoveries and reveals new things if you come back to observe the same phenomena several times. This experience describes how one experience may lead towards new experiences in living nature and motivate further exploration.

Theme 2: ***You have to know what to look for, so you don't just look for anything that doesn't matter***

- The statement "you have to know what to look for, so you don't just look for anything that doesn't matter" implies that some criteria matter more than others in an observation. It brings forward the essential questions of what is significant in an observation, and who decide what matters.

- One of the teachers says that the students should be involved in deciding what to look for in an observation of living nature. This statement implies that the criteria for what matters in an observation are not given, and that an important part of practicing observation in school may be discussing these criteria with students.
- The skills of describing, systematizing, and explaining seem to interact with how the students observe, according to the teachers' experiences. When the teachers discuss what it means to practice different skills, they find it especially hard to distinguish between describing and explaining. These experiences suggest that practicing the skill of observation in school is complex for both teachers and students.
- Three of the teachers highlight the importance for the students to express what they observe by drawing, and how this makes the students involve and connect more senses. One of the teachers says that drawing "is a way to learn", and that students remember better if they make or draw something themselves, and that students may remember "colors better than the number of claws". These experiences highlight the importance of aesthetic learning processes and how drawing also could be a way of knowing.

Theme 3: *Being a teacher is to explain*

- When the teachers discuss their role as teachers, they say that teaching means to explain to the students. However, according to one of the teachers, explanations from the teacher may also prevent the students' own explorations. The dualism in these statements suggests that it could be crucial for the teachers to consider the order of explaining and observing in teaching.

Theme 4: You must know enough to see what you see

- When the teachers discuss what scientific observational practices are, their answers point in different directions. One of the teachers (Thomas) describes scientific observation in terms of "you must know enough to see what you see", while another teacher (Lisa) describes it in terms of "you don't always know what you are looking for". Yet another teacher (Tom) says that an open observation let "you notice things in a new way", however, he does not find an open observation to be very scientific. These statements demonstrate some of the complexity in defining scientific observational practices.

From the four themes that emerged from the interviews with the teachers, I developed four overall categories that describe the themes in a more general way: Theme 1 "You do not see any facial expressions in nature" was assigned to the overall category "The 'things' teachers and students observe in living nature". Theme 2 "You have to know what to look for, so you don't just look for anything that doesn't matter" was assigned to the overall category "Practicing the skill of observation". Theme 3 "Being a teacher is to explain" was assigned to the overall category "The role of the teacher in observation". Theme 4 "You must know enough to see what you see" was assigned to the overall category "Observation as part of a scientific practice" (Table 12). These overall categories were then used as categories in the interview guide developed for the interviews with the students in Phase 3 (as described in section 10.2.1).

Table 12: Overall categories developed from the themes that emerged from the interviews with the teachers.

Themes from the interviews with the teachers	Overall categories
Theme 1: You do not see any facial expressions in nature →	The 'things' teachers and students observe in living nature.
Theme 2: You have to know what to look for, so you don't just look for anything that doesn't matter. →	Practicing the skill of observation.
Theme 3: Being a teacher is to explain. →	The role of the teacher in observation.
Theme 4: You must know enough to see what you see. →	Observation as part of a scientific practice.

12.2 Students' experiences in Phase 3

In this section, I will present and discuss the main themes that emerged from the interviews with the students during Phase 3 and describe each of the themes. These themes describe essential aspects of the students' experiences with the four cases that demonstrate different modes of observation of living nature, developed in Phase 1, and the themes will help point to the significance of these experiences. Descriptions will include examples from the interviews and my comments and interpretations.

To begin with, I sorted the students' statements by the overall categories developed from the interviews with teachers. The themes (5 to 8) that emerged from the students' interview and how they correspond with the overall categories and themes from the teacher interviews, are presented in Table 13.

Table 13: Correspondence of themes from the teachers' interviews and the students' interviews, connected by a common overall category.

Themes from the interviews with the teachers	Overall categories	Themes from the interviews with the students
Theme 1: You do not see any facial expressions in nature ➡	The 'things' teachers and students observe in living nature.	⬅ Theme 5: There is much more to a butterfly than to a stone.
Theme 2: You have to know what to look for, so you don't just look for anything that doesn't matter. ➡	Practicing the skill of observation.	⬅ Theme 6: You should always look several times to catch all the details.
Theme 3: Being a teacher is to explain ➡	The role of the teacher in observation.	⬅ Theme 7: They [the teachers] have to observe a lot themselves to be able to show us how to do it.
Theme 4: You must know enough to see what you see. ➡	Observation as part of a scientific practice.	⬅ Theme 8: It becomes a kind of system, and then you have everything under control."

12.2.1 Theme 5: *There is much more to a butterfly than to a stone*

This theme is assigned to the category *The 'things' teachers and students observe in living nature*. Several statements from the student interviews express what the students perceive as being significant when they observe living nature. The statements give an insight into what is brought to the foreground in different modes of observation and how these things in living nature appear to the students.

What is living nature?

The students express that there is something more to living nature, compared to non-living nature. In the interviews, all students are asked to describe what it means that something is living, and what the difference is, for instance, between a butterfly and a stone. To this question, Elise answers:

> That animals have more colors (…) because a stone is just gray, and then just a shape, or other different colors, while a butterfly has sort of different patterns, different shape (…) there are wings, and there is a body where they are attached. There is much more to a butterfly than to a stone.[x]

According to Elise, there is something more to a butterfly compared to a stone. This notion that there is something more to the living, is recurring in all the interviews. Sebastian thinks that “it's more fun to study an earthworm than a stone”, because “much more happens with an earthworm than with a stone.”[y] And when Emma compares a stone to a butterfly, she finds it more interesting to study a butterfly because “they have a lot of details”[z]. Later in the interview she says that “it [the stone] stands completely still all the time, and it has very little color.” [æ]. In the interview with Peter, he says:

> Peter: It is much easier to draw a stone as it stands still, but a butterfly can (…) fly away, and the butterfly moves quite often. It doesn't stand still when you draw it. And then there is much more to the butterfly than there is to a stone.
> Me: What is much more to it, you think?
> Peter: What it eats, a lot happens to it since it moves and there is something about it since it is alive.
> Me: ... and what does it mean that something is alive, do you think?
> Peter: It means that it has feelings, and that it is kind of..., it's kind of hard to explain.[ø]

As Elise, Peter also expresses verbatim that “there is much more to a butterfly than there is to a stone”, and according to him, what is more is “what it eats” and that “a lot happens to it since it moves”. Then he says that “there is something about it since it is alive”, but what this something is, seems to be a puzzle to him. He says that when something is alive, “it has feelings”, but it is “hard to explain”.

Oliver expresses that there is something more with the living in yet another way. In the interview, he starts to talk about what is more valuable:

> A stone is perhaps worth quite a lot if it's a …, for example a fossil. You've never seen dinosaurs, but it's only fossils that are signs that they lived (…) What I think is a bit strange is that a living animal costs much less than fossils, which are like stones that have never lived, I think that is a bit strange. (...) Stones are just hard, for example, those fossils are very hard, but those animals are alive (…) If, for example, it is a fossil that someone has seen before, it may not be worth much, but if it is a fossil

> that no one has seen before, which is, for example, very small or very large, then it can cost quite a lot.[å]

Here, Oliver expresses what I understand as an astonishment over the fact that in some cases a stone may cost more than a living animal. I don't know where he has learned this, but he seems to have heard that especially fossils may cost a lot. He finds it strange "that a living animal costs much less than fossils", and argues that "stones are just hard", but "those animals are alive". The statement may imply that being hard is the opposite to being alive. It seems that the stones being "just hard" means that they lack some features compared to the living. Again, the statement is an expression of the students' perception that there is something more to living nature, compared to non-living nature.

Entanglement and the changing nature of living beings

What seems to be some of the essential aspects of living nature according to the students, is how living organisms change and are entangled in one another. These aspects of change and entanglement in nature are especially brought to the foreground when the students study the images of the life cycle of different species of butterflies, made by Maria Sibylla Merian. Oliver describes the picture of the peacock butterfly (*Aglais io*) like this:

> Oliver: I see that there are two butterflies, with both sides in a way, one [side] that shows the back which is a bit like black and brown (…), and the nice side, which is sort of like the peacock butterfly, …a bit like the peacock, …a bit like that sort of colors. And then I see a caterpillar that is almost falling from the tree, and slightly pointed leaves, and two flies, and a fly that smells an egg, I think, and a pupa that is almost becoming a butterfly, and a pupa that maybe just entered [into the state of being a pupa]. Then I see a nettle-plant where everything is placed.
> Me: Why do you think she painted everything like that?
> Oliver: Because she wanted to show a story perhaps, ... a transformation, from first an egg and then a caterpillar maybe, and then sort of a pupa, grown pupa and butterfly (…).[aa]

According to Oliver, Merian wanted to show a story of the butterfly's transformation from egg to larva to butterfly. The picture of the peacock butterfly that Oliver describes has no explanatory text, still, it seems that the picture itself tells a story of transformation and entanglement that Oliver immediately grasps. In the picture he sees both growth and transformations, and some of the interwoven patterns in the larger world that the butterfly belongs to.

Some statements also reveal how entanglement of living organisms may be perceived by the students in yet another way. To the question of whether there is a difference between observing a butterfly and a plant, Sebastian doesn’t answer directly. Instead, he describes the difference between a plant and a butterfly like this:

> Sebastian: Not so much [difference] I think, because the butterfly has a kind of stamens too, or very similar, which are actually the antennae, so they look quite a bit like a flower. Isn't it the case that they also take pollen and spread it?
> Me: Yes, they can also do that, so they are somewhat connected in a way, is that how you think?
> Sebastian: Yes, and then very much is camouflaged, they [the butterflies] camouflage themselves on flowers, I think.[bb]

According to Sebastian, it seems that butterflies and plants are entangled in such a way that it might be difficult to distinguish between them. The statement seem to demonstrate how the things in living nature come into being to the students, not yet fixed and delineated.

Other statements express how the students see the difference between plants and animals. Although all the students agree that plants are alive, they seem to hesitate somehow. For instance, Emma says that “it [a plant] lives in a way…”[cc] , and Mia says: “Yes, they [the plants] live since they have roots that enable them to live, I think...” Then she continues and says that a tree is alive because “the leaves sprout, or that leaves become leaves and such, that they change color and such. I think so.”[dd] What seems to be essential to Mia here, is that the tree is alive because it changes, the leaves sprout and become leaves, and the leaves change color. Later, in the second interview, Mia says:

> Mia: Butterflies are in a way a bit more alive, but plants are also very alive. Butterflies are very much like…. First, they are an egg, I think. Then they become a pupa, and then a caterpillar, and then it turns into a

> butterfly (…) It takes a bit longer in a way, or .... plants can also take a long time to grow up, but it's not as complicated in a way.
> Me: Is there anything similar then?
> Mia: Hmm ... That both will ... grow and become really nice, and maybe get a pattern and such.[ee]

Mia's statement seems to suggest that there are degrees of being alive, and that the butterflies are more alive because they change more, and their life cycles are more complicated. Thus, the degree of ability to change seems to be an essential aspect of living organisms. In addition, Mia says that both plants and butterflies will eventually become "really nice", and this might imply that plants and the butterflies share some aesthetical characteristics as living organisms.

There are also other statements from the students that point toward a perception of some aesthetical features of living nature. By aesthetical features, in this context, I mean features that appeal to the senses. For instance, Mia writes that "it smells like nature" in one of her notes from the outdoor observations. In the interview, I ask her to describe what she means by that. Mia answers: "Because there is a certain smell in nature, you can just feel it in a way. […] Yes, I really like sitting in nature."[ff] I think what Mia describes here might be a certain sensation of being in nature that she likes, but that she finds difficult to describe in words because "you just feel it". In another interview, Peter describes what he means by "the leaves feel like cloth" in his notes from an observation outdoor:

> It was such leaves, a bit like, …very, very, very like cloths ... It was a bit wet too, then it [the leaf] becomes like a cloth. (...) There was a bit of water on it [the plant] and then I touched it.[gg]

Peter has touched the wet leaves on a plant and seems to associate this with what is probably a more familiar sensation of touching a wet cloth. According to the above statements, nature appeal to the students' senses in different ways. There are things in nature that they perceive as looking nice, smelling good or that are soft to touch. This sensation of nature that the students describe indicate that nature seem to offer or invite the students to aesthetical experiences.

The becoming of 'things'

Other statements express how some things are brought to the foreground while the students are observing either plants or animals, and how these experiences may open to new experiences for the students.

When Sebastian is asked whether he has made some discoveries after working on the second case of Merian and the butterflies, he answers:

> And then I have discovered a lot of new things about butterflies, what they look like and so on. When I see a butterfly, I kind of think, yes, it's yellow -- and red, but then I kind of saw that they're not just that.[hh]

Here, Sebastian describes how the butterflies are not just yellow or red to him, anymore. The statement implies that the butterflies have become more diverse to him and that he sees more details and nuances. This statement indicates that butterflies have been brought to the foreground, and that they have become more significant to Sebastian.

All these statements under Theme 5 express in different ways how the students perceive the things in living nature. The notion that there is "something more" with living organisms, compared to the non-living, is recurring in all the interviews. What this "something more" might be to the students, is ambiguous. However, some essential aspects concerning how the students perceive the living emerge from the interviews: compared to a stone, a living organism has more colors and details, and more happens to it. In addition, a living organism grow, change, and interact with other living organisms. Some of the students describe how living organisms and nature appeal to their senses in different ways, which may indicate that such aesthetical experiences are an essential aspect of living nature for the students. Furthermore, living organisms seem to become significant things to the students as they become more experienced observers. Gradually, the students see more details and more nuances.

12.2.2 Theme 6: *You should always look several times to catch all the details*

This theme is assigned to the category *Practicing the skill of observation*. In the classroom and in interviews, the students demonstrate how they observe, both by describing and drawing different pictures of plants and animals, and by describing plant specimens. They also express more directly what it means to be a good observer. Their statements give an insight into how the students perceive the skill of observation.

Observing details

The importance of noticing details when observing either animals or plants, seems essential to the students, and is repeatedly mentioned in different ways in all of the interviews. All students demonstrate a fine-tuned ability to observe details when asked to describe what they see. Below, Sebastian describes what he sees in a picture of a peacock butterfly (Picture 5). As part of working with the case of Merian, the students in groups studied and made models and sketches of the life cycle of five selected species of butterflies. One of the selected species was the peacock butterfly. Sebastian says:

> So, on the peacock butterfly, it's important to note that it's quite red on the wings and a bit browner down here on the other two wings. Then it kind of has eyes on the wings, and then it's a bit of white around the wing ..., around the eyes in a way. And then in front it has a bit like zebra stripes right by the antennae.[ii]

Sebastian's description of the picture of a peacock butterfly demonstrates how he sees details like nuances of red and brown in the wings, he sees the "eyes" with a bit of white around them, and he also notices the tiny zebra like pattern on the edges of the wings nearby the antennae. The statement demonstrates Sebastian's ability to express in words what he sees.

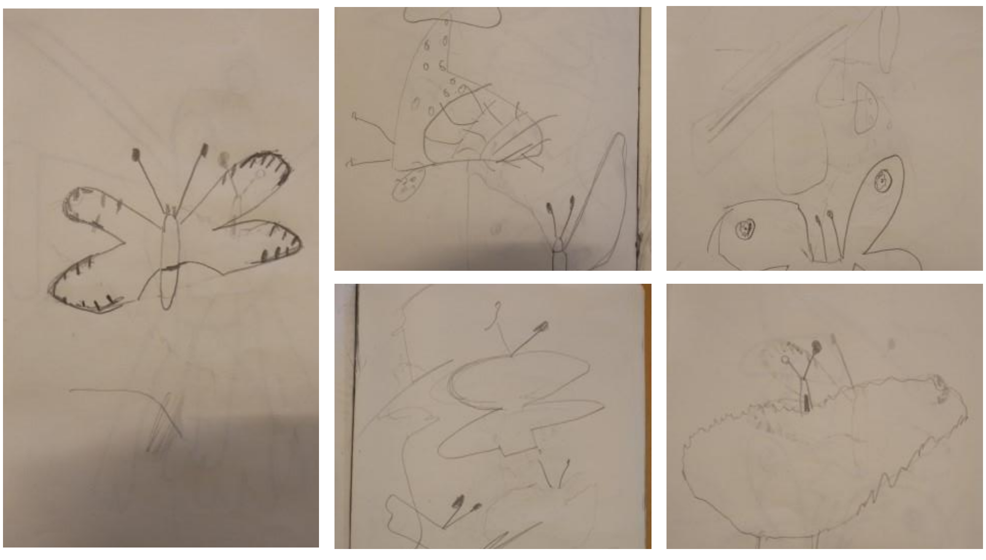
Picture 5: Picture of a peacock butterfly.[26]

[26] From: https://www.artsdatabanken.no/Pages/144817/Dagpaafugloeye

Another way of expressing what the students observe is by drawing, and to Sebastian this was more difficult than verbally describing what he sees. During my observation in the classroom, I noticed that Sebastian struggled to sketch some butterflies as part of an exercise in the classroom (Picture 6) and he seemed a bit annoyed. In the interview afterwards, I asked him whether he felt that there was a gap between what he saw in the pictures of butterflies and what he managed to sketch, and he answered:

> Sebastian: Yes! Because the pencil doesn't go the way I want it to.
> Me: Yes, it's not that easy, there's a difference between seeing and drawing it?
> Sebastian: Yes. We were going to draw a shark or something like that once, then I wanted there to be a fin on top, but it just turned out to be a lump, it was very annoying.[jj]

Thus, Sebastian confirms that he finds it difficult to draw what he sees. For instance, although he saw a shark-fin, he was not able to draw it as he saw it, and it just turned out as “a lump” on the shark’s back. This could indicate a lack of drawing skills but also be due to a lack of practice and time. In his notebook, I found another drawing of the privet hawk moth (Picture 7), that was not part of the exercise of sketching butterflies initiated by the teacher. I don’t know when he drew it, but his group was studying the privet hawk moth during the project about Merian. In the drawing he used colors and clearly studied the particular details of this butterfly.



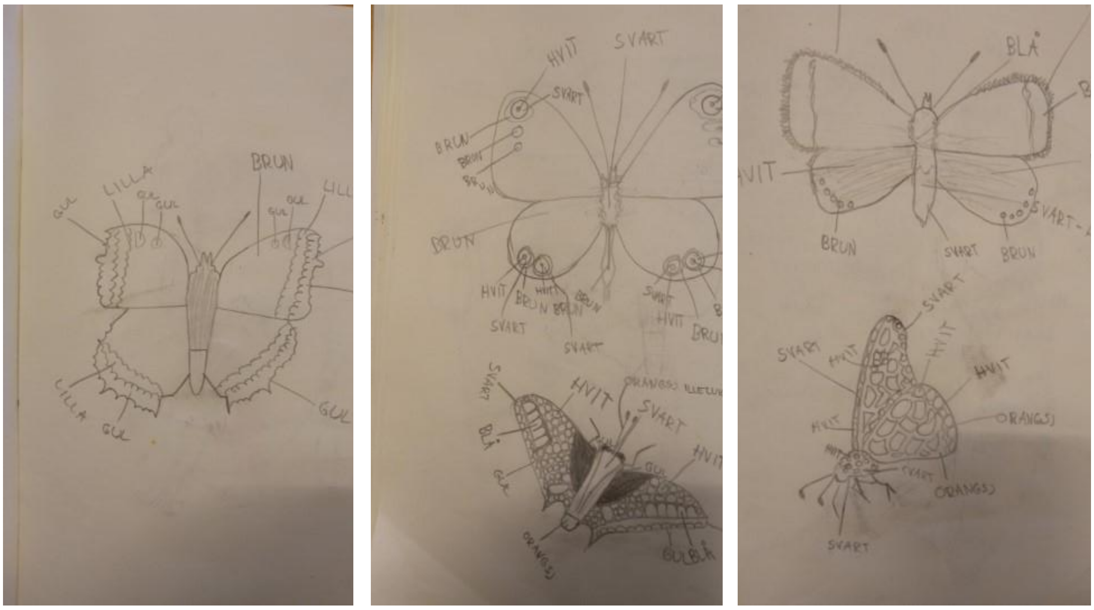
Picture 6: Sebastian's sketches of five different butterflies

Picture 7: Sebastian's drawing of the privet hawk moth

Emma finds it easier to express the details she sees by drawing than by using words. When she describes verbally what she sees, she has rather short replies, like when I ask her to compare two pictures of the peacock butterfly and the privet hawk moth and describe the difference:

> Emma: They have slightly similar colors, but they don't have the same shape.
> Me: What is the difference in the shape of the wings?
> Emma: It's more like ... it's much longer”[kk].

According to Emma’s statement above, she does not seem to observe many detailed differences between the peacock butterfly and the privet hawk moth at all. However, I think it is rather a question of the ability to express what she sees with words. When she does the same exercise as Sebastian and sketches different butterflies, the result is quite different, both compared to her own verbal descriptions and to Sebastian’s drawings (Picture 8). In her drawings, she depicts the butterflies with a lot more details than what she does in her verbal description. Her drawings describe the shape of both wings and body, the patterns on the wings, and even point to the colors in the different parts of the patterns of each butterfly.



Picture 8: Emma's sketches of five different butterflies

In the exercise, the students were told by the teacher only to use their graphite pencil and not their color pencils, and sketch rather quickly the most important features of each butterfly. Emma liked the exercise, but would have liked to have done it even more carefully, and she comments the exercise like this:

> Emma: It [sketching butterflies] was a lot of fun, but also a bit difficult because you couldn't include everything [in the drawing].
> Me: Would you have liked to draw it even more carefully?
> Emma: Yes
> (…)
> Me: If you were to describe a butterfly to someone else, would you think it would be better to draw it than describe it in words?
> Emma: Yes
> Me: Then you would have liked to be allowed to spend even more time and use colors [in the drawings] as well?
> Emma: Yes [ll]

Here, Emma confirms that she finds it better to describe a butterfly by drawing it, rather than describing it verbally. She would also have liked to use colors and spend even more time on the drawings. From the description of the previous theme, 'having colors' seemed to be one of the essential characteristics of a living organism, according to the students. To Emma, details of color also seem essential in her drawings of the butterflies. When she is not allowed to use color pencils, she writes which colors the different parts of the wing patterns have instead.

Sebastian’s and Emma’s statements and drawings show that they are both able to observe details, but their ability to express what they observe, either verbally or by drawing, differs. Sebastian, on the one hand, describes the peacock butterfly in great detail in words, but is not able to draw the same details, whereas Emma on the other hand, draws the butterflies in great detail, but is not able to describe the same details orally. However, in both cases, details of color seem essential to their descriptions.

In the interviews, both Sebastian and Emma express that they thought it was fun to make models of the life cycles of butterflies during the project week about Merian. The models were made as small dioramas in shoeboxes where all four stages of the butterfly’s life were demonstrated, in addition to the specific hostplant on which the larvae feed and live (Picture 9). The students worked in groups and cooperated to make the different parts of the model.

Picture 9: Dioramas showing the life cycles of the privet hawk moth made by Sebastian’s group (to the left) and of the peacock butterfly made by Emma’s group (to the right).

Sebastian’s group made a model of the life cycle of the privet hawk moth. During my observation in the classroom, I noticed that Sebastian worked on the caterpillar for a long time and proudly showed it to me when I asked him if I could take a picture (Picture 10). In the interview, I asked him what characteristics of the caterpillar he found important to portray in the model, and whether he enjoyed the task:

> Sebastian: The red here in the middle, it's a distinguishing mark, and that horn in front. …and maybe get that [some marks] on the back of the body...
> Me: How did you like making a caterpillar?
> Sebastian: It was quite fun.[mm]

Picture 10: Sebastian's caterpillar

Making models, by using paper, colors, shoeboxes, model clay, paint, and pipe cleaners, seemed to appeal to both Emma and Sebastian, and most of the other students as well. All students engaged in the task, and at the end of the of the project week they held an exhibition for the students in first grade.

Being a good observer

When the students are asked more directly what it means to be a good observer, they also emphasize the ability to observe details, like Peter:

> Me: What does it mean to be good at observing then? What do you think?
> Peter: Seeing those details in a way, seeing the best details…
> Me: (…) What is it to see the best details?
> Peter: It might be... for example, it has such small hairs, then you sketch very small hairs. If it has, for example, something different from another

one (…), then you observe it very well. If you, for example, see the difference between two similar species that [still] are different in some ways.[nn]

What seems significant to Peter's statement, is that for him some details may be more important to notice than others when observing living nature, especially if those details make it possible to separate between species that might look very similar at first. As if it was an expansion of Peter's reply, Sebastian describes how to practice seeing those details:

> Maybe don't just look like once, and then you see something and then you think that there is nothing more, and then you look once more, and you see more. So, you should always look several times to catch all the details.

Sebastian's statement implies that, when observing living nature, details reveal themselves when you look several times and that there is always more to see.

Doing observations outdoors

Another aspect that emerges from the interviews with the students, about how to practice the skill of observation, is the importance of doing outdoor observations in nature. For instance, Sebastian suggests to "maybe take a few walks in the woods to look for some small insects to see if there (…) is a new one you haven't seen before."[oo]And to the question of whether it matters if you observe plants in the classroom or outdoors, Mia answers:

> Mia: It might be a little easier outside.
> Me: Why is that?
> Mia: Because then you can kind of see when it stands up in a way, stands upright.
> Me: Yes …and why is it better?
> Mia: Because then you can see where you get it [the plant] from (…) That can be an advantage.[pp]

Elise says that: "If you are out looking at real plants, you get more than a picture, since then you can turn the plant around and look closely".[qq] According to both Mia and Elise, there is a difference between observing a plant in the classroom, or in a picture, and observing a plant in nature. Elise puts into words the experience that a real plant is something more than a picture. The statement indicates that an experience in nature is different from, and gives more, than a representation of a plant. A picture of a plant is always a mediation where someone has decided what features are significant and thus show in the picture, and what matters or not in the description of the plant, while a real plant can be turned around and looked at from many sides.

When I ask Peter what it means to be a good observer, he brings attention to another aspect of observing real and living organisms in nature:

> Peter: Don't know... be quite quiet
> Me: What do you think about that? Or what do you mean?
> Peter: It's a bit difficult … if you're going to get some things to come close to you, for example a bird, then you must sit completely still, if you make noise, you might scare it away.[rr]

According to Peter, to be a good observer, you must have the ability to "sit completely still" to get, for example, a bird "close to you", and not "scare it away". The statement implies that to observe living organisms in their natural environment requires of us to be attentive and considerate for us to see and hear them, to let them show themselves.

All statements by the students under theme 6 express in different ways how the students perceive the skill of observation. The students demonstrate and explicitly emphasize the importance of observing details. The examples of Emma's and Sebastian's descriptions of butterflies show that the students have different abilities to express what they see. While Emma prefers drawing, Sebastian prefers describing what he sees verbally. Furthermore, according to the students, to practice the ability to observe you should always look several times, and observe real plants outdoors, to "see more".

12.2.3 Theme 7: *They [the teachers] have to observe a lot themselves to be able to show us how to do it*

This theme is assigned to the category *The role of the teacher in observation*. In the interviews, the students express how they think the teachers might help them to become good observers. The statements give an insight into how the students perceive the role of the teacher in observation.

The students have different views on how the teacher might be able to help them to observe living nature. To the specific question on how the teacher might help her to be a good observer, Emma says in the first interview: “I am not quite sure”[ss]. However, in the last interview, her answer to the same question is: “To do it more in school”. When I ask her to elaborate on what the teacher might do, she says: “draw it”, and then the conversation continues like this:

> Me: Why is that?
> Emma: Because then you get ... then you draw details and then you see the details in a way, if you draw them in detail.
> Me: You see it better if you draw, compared to if you don't draw?
> Emma: Yeah, think so.
> Me: Why do you think so?
> Emma: Because if you are careful, you look carefully at what you see in the picture.[tt]

According to Emma, the teacher might help the students to become good observers by letting them do more observations in school and, more specifically, by drawing what they observe. She is not clear about whether the teacher or the students, or both, should be drawing, but she says that “then you draw details and then you see the details”. Thus, to Emma, there seems to be a clear connection between drawing details and observing details, and to become a good observer you have “to do it more in school”. Sebastian also emphasizes observation as something you must do:

> Sebastian: They [the teachers] must observe a lot themselves to be able to show us how to do it.
> Me: Yes, why is that?
> Sebastian: Because if they try to teach us how to observe, and then they don't see all the details that we should have seen, then we lose some of the details that we should have seen.[uu]

Sebastian suggests that the teachers should observe a lot themselves to be able to show the students how to do it. Thus, both teachers and students must practice the skill of observation to be good observers. When I ask Peter about how the teacher might help him to become a good observer, he says:

> Tell what you have to look for… To see if it's a male or female. Then they can tell what color the male has and say what color the female has, then you'll find what type… or if it's a male or female, or what bird it is, whether it has a pointed or sharp beak or what it does.[vv]

To help Peter to be a good observer, the teacher should tell him what to look for, e.g., to know what species of bird it is, or to separate between male or female, for instance.

These statements under Theme 7 express in different ways how the students perceive the role of the teacher when observing living nature as part of teaching and learning in school. Both Emma and Sebastian say that observation is a skill that needs to be practiced in order to become a good observer. The students think that the teacher may to improve the students' observational skills by letting them "do it more" and by showing them how to do it. Peter brings in another aspect of the role of the teacher in observation by saying that the teacher could be helpful by telling him what to look for.

12.2.4 Theme 8: *It becomes a kind of system, and then you have everything under control*

This theme belongs to the category *Observation as part of a scientific practice*. Several statements from the interviews express how the students perceive the scientific practices that are demonstrated in the four cases from the history of science. During the interviews, I did not ask the students directly about what scientific practices means. Instead, I asked them to tell me about how the main character in each case investigated nature. The statements give an insight into how the students perceive some essential aspects of these scientific practices.

After working on the second case of Merian, Oliver has a lot to say about how Merian did her investigations of butterflies:

> Oliver: She observed them [the butterflies] a lot. If she found, for example, a new caterpillar then she took it home, and then she had it there and fed it and looked after it, and everything like that, and then she waited to see what happened to it. And then most of them ..., all the animals that she had captured, they had (…) laid eggs, then they had become caterpillars, then they had become pupae and then they had become

> butterflies. And then she had made over fifty such observations, and then she wrote down what happened every day.
> Me: […] In what way was she a scientist or a researcher?
> Oliver: Perhaps because she was the first biologist, who without education just managed to figure it out.[ww]

Oliver describes how he perceives what Merian did to investigate the butterflies. He says that she "looked after it", "observed them a lot", and "waited to see what happened". What made her a scientist, according to Oliver, is that she "without education just managed to figure it out".

The students also have several things to say about Linné's systematic way of observing plants. Elise says:

> He [Linné] pressed those [plants], I think, and then he put them [the pressed plants] in shelves that he could move. And then he probably took some sheets and glued them [the plants] on sheets (…), and then he put them [the sheets with pressed plants] in shelves, and then he probably wrote notes where the names of those things [the plants] were written, and then he perhaps used boxes in which he put them [the notes].[xx]

Oliver elaborates and says that "he [Linné] liked to organize things, he didn't want things so messy, since it made it difficult to locate what he wanted". [yy] In the interviewa, I also ask the students about what it means to be systematical. Emma says that it means "to sort it in a way, or for example, if you have a lot of seeds in a box, you could rather have them in smaller boxes and have the same seeds in one box".[zz] And Sebastian explains what it means to have a system:

> That, for example, you have a shelf with drawers, then you put the blue flowers in a drawer, and then the red and then the yellow [flowers], and then, when you've done that, it becomes a kind of system, because then you have everything under control. […] Then it becomes easier to observe, easier to keep track of.[ææ]

According to Sebastian, when you have made a system "then you have everything under control". I think, it is not obvious what Sebastian means here by having everything under control, but he says it becomes easier to observe and to keep track of. The statement is interesting, and it points to an essential aspect of systematizing living nature, and maybe also to an illusion, that when you have a system of nature, “you have everything under control”.

About Darwin and Wallace’s way of exploring living nature, Sebastian says:

> Because in England there are certainly not as many tropical animals as there are around the Amazon and all those rainforests. They [Darwin and Wallace] were there to see what animals looked like there, then they sort of got a different view of what animals really were like.[øø]

I also ask Sebastian how Darwin and Wallace arrived at their explanation, and he says that “I remember that they sent letters to each other and then (…), I think it was Darwin, he had a greenhouse in the garden and did a lot of experiments and such”.[åå] In these statements, travelling to “get a different view” and experiments emerge as central aspects of a scientific practice.

The above statements under Theme 8, express how the students perceive some essential aspects of observation as part of a scientific practice. They express how Merian observes, waits, look after the butterfly, and takes notes, and how Linné sorts his plants and makes a system “to have everything under control”. One of the statements also express the significance of traveling to other part of the world to observe living nature, as in the case of Darwin and Wallace, to get a different view of what living organisms are. These statements demonstrate that the students may recognize aspects of scientific practice and make them meaningful case-by-case.

12.2.5 An overview of findings

In the previous sections, I have presented and discussed four themes (5- 8) that describe essential aspects of how the six selected students experience different modes of observing living nature demonstrated through four historical cases. (cf. research question 3). I would like to highlight the following findings:

Theme 5: *There is much more to a butterfly than to a stone*

- In the process of observing living organisms, these gradually become significant and more nuanced to the students. The things in living nature seem to be brought into existence for the students through the activity of observing them.

- The students recognize living beings as something else than nonliving nature and describe living organisms as having more colors and details, and as growing, changing, and being entangled with other living beings. They say that there is “much more” to a living organism, but also that it is “hard to explain” what being alive means.
- Living nature offers aesthetical experiences and appeals to the students’ senses in several ways. In these experiences, there seem to be complementarities between the nature of living beings, as being colorful, mobile, dynamic, interacting, having a lot of details to discover, and the students’ approach to observing them. These experiences bring forward the importance of aesthetic and embodied learning processes when observing living nature in school.

Theme 6: ***You should always look several times to catch all the details***

- According to the students, you should always look several times to see all the details and observe real plants in nature when practicing the skill of observation. One of the students says that “you look once more, and you see more”. This experience describes how one experience may lead towards new experiences in living nature and motivate further exploration.
- All the students demonstrate how they notice details when they describe specimens or pictures of living organisms, and they explicitly emphasize the importance of observing details. However, the students demonstrate different skills on how are able to express what they observe. These experiences underscore the importance of letting the students respond to and practice expressing their observations in different ways.

Theme 7: ***They [the teachers] have to observe a lot themselves to be able to show us how to do it***

- The students recognize observation as a skill they need to practice. They say that the teacher should help the students by showing them how to observe living nature. However, the students express different views about what this “showing” entails. One of the students says that the teachers “have to observe a lot themselves to be able to show us how to do it.” These statements imply that the students expect the teachers to demonstrate skilled observational practices themselves in their teaching.

Theme 8: ***It becomes a kind of system, and then you have everything under control***

- Through the stories of the four historical cases presented in the classroom, the students recognize some essential aspects of observational practices in science, like observing carefully, taking notes, and making systems. These statements demonstrate that the students may recognize aspects of scientific practices and make these practices meaningful to themselves case-by-case.

12.3 Teachers' experiences in Phase 3

Right after the teachers had applied all the four cases in school in Phase 3, I interviewed them a second time. In this section, I will not introduce new themes, but rather explore and discuss how the teachers' experiences from Phase 3 expand or develop the themes that emerged from the interviews with the teachers in Phase 2. In the last section of this chapter, I will come back to and discuss both the students' and the teachers' experiences together.

When I ask the teachers to describe their experiences with applying the four cases in their teaching, they emphasize different aspects, e.g.: the project was fun, the students were engaged and interested in the four cases, observational practices are fundamental skills in science, observation may be used as a method in several subjects, the project had an overarching theme and an interdisciplinary approach, the teamwork was both rewarding and challenging, and took time. Lisa, Tom, and Victoria all mention the case of Merian as particularly successful in terms of the students' engagement and interest.

In the following, I will elaborate on what the teachers, after having been part of this project, expressed about 1) what it means to practicing observation when teaching about living nature, 2) their experiences with the case of Merian, and 3) their role as a teacher. The teachers' experiences from Phase 3 especially add to the following themes from Phase 2: Theme 2: *You have to know what to look for, so you don't just look for anything that doesn't matter* assigned to the overall category "To practice the skill of observation". Theme 3: *Being a teacher is to explain"* assigned to the overall category "The role of the teacher in observation".

12.3.1 The skill of observing living nature

In theme 2: "You have to know what to look for, so you don't just look for anything that doesn't matter", I describe what the teachers say about how to practice the skill of observation in school in Phase 2. The teachers describe their ambivalence about whther to tell the students what to look for or not, when practicing observation. The theme also raises issues about how different skills like observing, describing, systematizing, and explaining, are related and partly merge into each other.

After having worked with the four cases in phase 3, I ask the teachers again what it means to practice the skill of observation. In the following, I will present all five teachers' response to this question. Thomas says that "in the same way that you practice other things, if you want to be good at cycling then you have to ride a bike, and if you want to become good at observing, then you have to observe.".[aaa] Victoria also emphasize the importance of making observations: "It's probably a good idea to practice it many times (…) That they [the students] get a concrete thing to observe (…) And make them aware of using their senses (…)." [bbb] Lisa says: "Presence and focus, that the students are focused, and we are focused on what we are doing, and not doing everything else. So, it [practicing the skill of observation] must be focusing."[ccc] And John, for his part, emphasizes how to create good conditions for focusing: "It's about creating situations where you focus on different objects, or parts of objects, and have time, not least, and calmness. So, the surrounding factors must also be in place to be able to get the focus that needs to be there."[ddd] Tom expresses his thoughts about practicing observation in school like this: "Through observation tasks where you are told to observe something (…) whether you look for something special, or whether you don't (…)", and he elaborates "then you [the teacher] ask reflective questions to the student so that he also sees other things, or sees it from a new angle, what about this, or what about... (…) Then they [the students] notice it. …Don't know, I think it's practicing observation.[eee]

According to the teachers, the important elements in practicing observation in school are "to observe", "do it many times", and "get a concrete thing to observe". Both the students and the teachers need to practice "presence and focus", and the teachers must create situations where the students "have time and calmness". The students may also practice observation through "observation tasks where you are told to observe something" and reflective questions that may make them see other things. The teachers' answers in this second interview seem to demonstrate a clearer emphasis on practicing observation by doing it. To larger degree, they emphasize creating conditions in which the students can focus and notice new things, rather than telling the students beforehand what to look for.

I also asked the teachers about the importance of observational practices in an education about living nature. Tom's answer to this question is:

> I think people are surprised by how much biological diversity you have around you. I don't think people look at the grass, they only see grass there, but if we look [carefully] there are different types of grass, there are also other plants in between, you see mushrooms and insects, so you have quite a large biodiversity within a fairly small area if you just look. But I think people don't observe nature, they just walk past it.[fff]

Several of the teachers similarly emphasize that the purpose of practicing observation of living nature is "to make the students aware of things" (Lisa) in nature, and more particularly "raising awareness about the different species" (Victoria) and "observing the function of different species as part of a whole" (John). Thomas answers the same question as this:

> (…) what you observe, have seen, what you have felt, what you have smelled, what you have said, you remember better than things that you have been told (…) Nature is not as close to us in 2020 as it was for those who grew up a hundred years ago, and two hundred years ago. And presumably it may not come closer [to us] unless we seek it out (…).[ggg]

Thus, what the teachers express here is that by practicing observation of living nature the students may notice more and become aware of things in living nature, and that the students may even come closer to nature as part of the process. Thomas also indicates that there is an increasing distance between people and nature today, compared to a hundred years ago, that may make the observation of living nature an even more urgent issue than before.

12.3.2 The case of Merian

Lisa, Tom, and Victoria mention the case of Merian as particularly successful in terms of the students' engagement and interest. Here, I will elaborate on what the teachers say about what they perceive as the success criteria in working with this case.

When I ask Lisa what stands out to her, while working with four cases in school, she describes the experience like this:

> Lisa: I think the butterflies were the best because you could see that they [the students] brought out so much detail, especially when they painted the butterfly (…) When they were then able to transform it into their own,

there were many details there, with those eggs underneath [the leaf] …, and what type of leaf and ... (…). I think maybe that was the best. After all it is very pleasing to work with butterflies.
Me: Why is that?
Lisa: Because they [the butterflies] are so beautiful. They [the butterflies] are catchy with these colors.[hhh]

Victoria says that she thinks the students remember the case of Merian the best, and like Lisa, she mentions: “It's very colorful (…) I think it sticks a little better [in the students’ memory], those very colorful butterflies”. Victoria also mentions other aspects that might be important:

> “I think everyone was a little familiar with them [the butterflies] before, …the life cycle of butterflies (…) They [the students] probably felt it was a bit familiar to them at the start too. So, I think that mattered. (…) I noticed (…) that they remembered a lot about Merian, where she lived, and the printing house of her stepfather (…). I think the story of Merian has stuck [to the students’ memory] as well.[iii]

At the end of the second interview, Tom talks about the historical cases and how the students find it hard to imagine how the world was 500, or even 300 years ago, but that the case of Merian seemed different. The conversation goes like this:

> Me: Perhaps the students could imagine more what it was like at that time…?
> Tom: I felt we got into it a bit when we talked about the smell and such at that printing house [where Merian grew up as a child].
> Me: Yes exactly. In that booklet (…) I played with the sensual [experiences] because that was part of her [Merian’s] approach.
> Tom: Yes, I think that worked well, I think so.[jjj]

In the statements above the teachers bring attention to what I think are essential success criteria with the Merian case: butterflies as phenomena, the students’ familiarity with the phenomena beforehand, and Merian’s aesthetical and holistic approach. As phenomena the butterflies are colorful and beautiful, with a lot of details to study, and they seem to appeal to the students’ senses in an immediate way. According to Lisa and Victoria the butterflies are “catchy” and “stick” in the students’ memory. Victoria also emphasizes the students’ familiarity with butterflies as something that mattered for the students’ engagement with this case. The students already had some experiences to build on, and by working with this case these experiences could be expanded to make the experience of observing butterflies richer to them.

In addition, the story of Merian was probably also experienced as being more familiar to the students than the other cases. The story starts with Merian as a young girl growing up, first in her father’s printing house, and after his death, in her stepfather’s painting studio, and how these experiences affected her. This starting point probably made it easier for the students to identify themselves with her and her approach to observing butterflies. Added to this, and inspired by Merian’s holistic and aesthetical approach, I also tried to tell the story by focusing on aesthetical experiences in different parts of the story. For instance, I invited the students to imagine the smells and sounds in the printing house that Merian walked around in as a child. When Tom refers to this in particular, he thinks that this approach made it easier for the students to imagine what Merian’s life was like at that time, and he thinks “that it worked well”.

Practicing observation of butterflies in this case and making dioramas inspired by Merian’s holistic and aesthetical approach, Lisa says that the students were “able to transform it[the task] into their own”. This might mean two things: first, that the students were given the opportunity to *transform it into their own*, and second, they managed to *transform it into their own*. The first aspect implies that the students were invited to participate in and contribute to a dialogue, rather than being someone who simply receives information. The second aspect, that they manage to do so, implies that the students were invited to participate on their own terms: starting with the familiar and colorful phenomena that appealed to their senses, telling a story about a girl that they could identify themselves with, and using familiar equipment and approaches to practice observation.

The case of Merian and her holistic and aesthetical approach to observation, also invited the teachers to apply an interdisciplinary approach. During the week in which the students worked with this case, the subjects of science, arts and crafts, Norwegian, and social studies blended into each other in a self-evident way. Lisa, as the arts and craft teacher in this context, was the one who came up with the idea of making the three-dimensional dioramas of the life cycles of butterflies. About the value of working in an interdisciplinary team, Tom says:

> It was Lisa's idea with those shoe boxes (...). I couldn't envision in my head what that was going to look like. She tried to explain it to me, and I just said: I trust that this will be fine, but I don't quite see how you're going to do it. And then I just trusted her and that it will be a good result (…). So, everyone contributes with their part, and it [the project] will be better than if one of us had done it alone. If I had done it alone, the whole thing would have been very Tom-shaped, maybe simpler, maybe squarer, maybe more what I am sure of. Whereas now we (…) have other inputs and other methods.[kkk]

With this statement, Tom describes the value of an interdisciplinary approach where the teachers can complement each other and bring in more “inputs and other methods”. The success of the Merian case seems to be based on the sum of butterflies as phenomena, the students’ familiarity with butterflies beforehand, and the aesthetical and interdisciplinary approach. With the implementation of the Merian case, the teachers seem to recognize the importance of aesthetic and interdisciplinary learning processes.

12.3.3 The teachers’ understanding of their role as teachers

In the second interview, I ask the teachers again what teaching means to them. Their immediate response to this question is that teaching means “transfer of knowledge to the students” (Lisa), “explaining things” (Thomas), “convey information” (Tom), “give knowledge to the students” (John), and “get the students started and guide them” (Victoria). Except for the last one, these answers seem to correspond with an understanding that “teaching is to explain” as discussed in Theme 3. However, after their immediate response several of the teachers nuance their statements. For instance, Lisa says: “Primarily it is the transfer of knowledge, but there is so much more to it. Because for me teaching means, in a way, teaching them to be humans.”[lll] She elaborates and says it’s about teaching the students how to “function in society”, how to “work with feelings” and how to “be with others”. Thus, although Lisa first describes teaching as a transmission of knowledge, she seems to describe the purpose of teaching in terms of *Bildung* and becoming a citizen in a democratic society.

John also elaborates on his immediate reply and says that teaching means to give students knowledge that is useful. When I ask how he can give knowledge to his students, he says:

> No, you can't give it [knowledge]. You can't fill their heads with knowledge, but we can facilitate the process, and then it [the question] is how we manage to facilitate that in a good way. (…) I'm very concerned with trying to make things practical. (…) This is important in all subjects, demonstrate as much as possible.
> Me: And why is that?
> Because I think there are a lot of students who learn the lessons, …the knowledge, …the competence then (…) …when they have tried with the whole body (…).[mmm]

In the statements above, Lisa emphasizes the greater purpose of teaching as tecahing the students how to function in society, and John says that knowledge should be useful and practical. John reconsiders his first statement of teaching as "giving knowledge" to the students and says instead that teaching is about "facilitating the process". John underscores that he is concerned with making things practical, however, exactly what he means by "facilitating the process" is unclear. Tom still seems to stick with a description of teaching as some sort of knowledge transmission:

> It is a form of communication; you convey information to the students that you want them to understand. The information can either be knowledge or it can be methods (…) how they should do things (…). It's about getting the students to learn (…) about the topics that we've decided we think are important for them to know something about. It's communication! Convey knowledge, what is in my head must enter the students' heads. Then it is necessary to find the right method to reach them (…) It is a constant process, and it is difficult.[nnn]

About practicing observation, Tom says: "You want them [the students] to see the same thing as you see. To observe what you observe when they [the students] observe a given phenomenon or a given thing."[ooo] In the interview, Tom repeatedly states that by applying more open forms of observation the teacher can't control what the students learn. However, Tom also says that:

> What we have done here with observation as a method (…), with them [the students] asking their own questions and finding their own answers (…), it has always been important, especially in science (…) You must learn scientific skills (…).[ppp]

I think there are some educationally important contradictions in the above statements by the teachers, like seeing teaching as a transfer of knowledge, and at the same time considering the purpose of teaching as teaching the students to be humans. Another such contradiction is seeing teaching as conveying information and "wanting the student to see the same things as you do" and at the same time recognizing the importance of the students asking their own questions and finding their own answers. The teachers seem to express an ambivalent attitude towards their role as teachers in teaching skills to their students; about whether they should lead the students and control the outcome, or whether they should rather invite the students to think for themselves. The last option comes with a risk that the teacher cannot control the outcome.

In addition to this ambivalence, the teachers still express an uncertainty about the difference between the skills of observing, describing, systematizing, and explaining living nature, in the second interview. Like in the first interview, the teachers still found that the different skills blend into each other. However, explaining is seen as higher in the hierarchy, meaning that if the students are able to explain an observation it implies a deeper understanding.

Thus, in some ways the teachers seem to lack a firm ground and orientation in their role as teachers in the context of practicing observational skills. When the teachers express what it means to practice the skill of observation in the second interview, they put more emphasis on creating conditions in which the students can focus and notice new things, or see more, through repeated observations, rather than telling them what to look for. Still, when describing their role as teachers, they seem ambivalent and uncertain about how to teach in such ways. This uncertainty may be due to a lack of own experience with practicing the skill of observing living nature, and maybe also a lack of a more general understanding of what scientific observational practices are.

12.3.4 An overview of findings

In the previous sections, I have described and discussed how the teachers' experiences from the implementation in Phase 3 add to the themes developed from the interviews with the teachers in Phase 2. I want to highlight the following findings:

Theme 2: ***You have to know what to look for, so you don't just look for anything that doesn't matter***

- According to the teachers, the importance of practicing observation is that students notice more and become aware of things in living nature. One of the teachers implies that the students may even come closer to nature. The teachers seem to recognize that the things in living nature are brought into existence for the students in the process of observing.
- When the teachers discuss what it means to practice observation with their students, they demonstrate a clearer emphasis than before the implementation, on creating conditions in which the students can focus and notice new things, through repeated observations, rather than telling them what to look for. Their statements point towards a teaching that facilitates experiences that motivate the students to further explore the phenomena in living nature.
- The teachers still express an uncertainty about the difference between the skills of observing, describing, systematizing, and explaining living nature. Like in the first interview, the teachers still found that the different skills blend into each other.
- Three of the teachers mention the case of Merian as particularly successful in terms of the students' engagement and interest. The teachers highlight what seem to be essential success criteria of this case: butterflies as phenomena, the students' familiarity with butterflies beforehand, and the aesthetical and interdisciplinary approach. With the implementation of the Merian, the teachers seem to recognize the importance of aesthetic and interdisciplinary learning processes.

Theme 3: ***Being a teacher is to explain***

- All the teachers express a somewhat contradictory attitude when I ask them what teaching means. One teacher says that "you want the students to see the same things as you do" when they practice observation, but he also says that it is important that the students are "asking their own questions and finding their own answers". These statements seem to imply an ambiguity of what teaching means when practicing more explorative observational practices with the students.

12.4 Discussing the teachers' and students' experiences

In this section, I will use the phenomenological approach I describe in Part II as a foundation for discussing the meaning of the teachers and the students' experiences with practicing observation of living nature in both phases two and three.

In Part II, I describe what I mean by a phenomenological approach according to the following four aspects: 1) as an ontology (a foundation for knowledge) 2) as an epistemology (a way of knowing), 3) as an education (a way of teaching and learning), and 4) as a research-method (a way of structured inquiry). A phenomenological approach to what being in the world means (ontology) has implications for how you understand knowledge and knowing (epistemology). In turn, the way in which you understand knowledge and knowing has implication for how you understand and practice both education and research.

The themes I have presented in the previous sections (Table 13), relate to both ontological, epistemological, and educational aspects of the phenomenon of observing living nature. Themes 1 and 5 describe how teachers and students perceive the things in living nature and includes ontological considerations. Themes 2 and 6 describes how teachers and students perceive and practice the skill of observation and relate to both epistemological and educational aspects. Themes 3 and 7 describe how teachers and students perceive the role of the teacher in observational practices and deal mainly with teaching and learning aspects. Themes 4 and 8 describe how observation is understood by teachers and students as part of a scientific practice, and touch upon both epistemological and educational aspects.

I would like to highlight some intriguing polarities in the themes that respectively describe the teachers' and the students' experiences: While one of the teachers describes "a lack of facial expression" in living nature, the students on the other hand describe that there is "something more" to the living in nature. While the teachers in the first interviews emphasize that "you have to know what to look for" to practice observation, the students emphasize that "you have to do it several times". While the teachers say that "the role of the teacher is to explain", the students say that "the teacher has to do it a lot themselves" to be able to show the students how to do it.

In the following, I will discuss teachers' and students' experiences against each other. I will elaborate on the findings from both phases two and three and the above-mentioned polarities in the students and teachers' experiences. I will structure the discussion by the overall categories: I. The 'things' teachers and students observe in living nature, II. Practicing the skill of observation, III. The role of the teacher in observation, and IV. Observation as part of a scientific practice.

12.4.1 The 'things' teachers and students observe in living nature

Findings from both phases two and three demonstrate that the students' and teachers' perception of the things in living nature is dependent on their lived experiences. However, while the teachers seem to struggle with recognizing and delineating entities in living nature, the students seem to be intrigued by living organisms being dynamic, inter-connected with other living beings, and having many colors and other details.

According to van Manen (2016b) "we see and recognize ourselves in the things of our world. And the things tell me who I am" (p. 307). For instance, in one of the teachers' reflections on what a species is, he uses the examples of ducks, oak-trees and mushrooms (Tom, section 12.1.1), and his lived experience as a hobby mycologist becomes obvious. In the same way, another description by one of the teachers of nature as "kind of endless" (Lisa, section 12.1.1) demonstrates how this teacher uses her experience as a diver to express how she perceives this sense of nature as being endless. In phenomenology, *the phenomenal field* is where we make all our experiences. A perception, like seeing a duck in the pond, or a mushroom in the woods, is not a linear response. According to Merleau-Ponty (2012), perceptions go through an 'intentional arc' that "creates the unity of the senses, the unity of the senses with intelligence, and the unity of sensitivity and motricity" (p. 137). This means that the body is an organism, and not a mechanism, and our perception of what things we see in living nature depend on our lived experience as human beings.

The importance of practicing observation is that the students notice more and become aware of things in living nature, according to the teachers in the second interview. Knowing the world means to address yourself to the world, and only by addressing yourself to the world can you understand what being is, according to Heidegger (1962). Findings from the interviews with both the teachers and the students demonstrate that the students start to notice more details and nuances of the things in living nature when they practice observation and respond to what they observe. Whether the students address themselves to the world by drawing a butterfly, counting petals in a flower, touching a wet leaf, or smelling nature, different things become significant. In these processes, entities in living nature are brought into existence to the students. At the same time, responding to the phenomena in nature, is part of the students' understanding of being and of becoming a subject. In other words, for the students to 'address themselves' to living nature and respond, is an existential question.

What we conceive as entities with fixed properties are dis-closed "in varying degrees of explicitness" depending "upon the way in which we are absorbed" in an activity, according to Heidegger (1962, p. 101). Different things becoming present as entities with properties to us is a process of *deworlding* in the sense that some things are brought to the foreground and fixed. When one of teachers says that "there is no facial expression in nature" (Thomas, section 12.1.1) it may indicate that he perceives nature as a background where entities are dis-closed with a low degree of explicitness. The many things in living nature have not become recognizable and significant to him (yet). However, this lack of recognition, could also be linked to 'the way in which the teacher is absorbed in the activity' of observing living nature. In this case, the teacher perceives nature and the living organisms therein as something fundamentally different from human beings, and because of that he seems to find it difficult to make meaningful observations of them.

While this teacher expresses "a lack of facial expression" in nature, the students on the other hand express that there is "something more" to living organisms compared to non-living nature. The students seem to be able to identify themselves with living organisms as beings. For instance, Peter's statement about sitting still in nature in order to see a bird (Peter, section 12.2.2) demonstrates his ability to recognize the bird as a being with its own needs that must be taken into consideration if you want to observe it. When the students observed earthworms in a terrarium in the classroom, the students had questions like: "How do they sense [their environment]?" and "How do they pee?" (Notes from observation 29.10). And when they observed different insects in pictures, they had questions like: “Do insects have blood inside? Do insects cry? Do insects feel pain? (Notes from observation 26.11). These questions imply that the students to a certain extent identify themselves with the earthworms and the insects they observe. The students see them as living beings and assume that they have similar needs and feelings as human beings. We might say that while the students look for ‘a facial expression’ in the earthworms and insects, the teachers on the other hand experienced ‘a lack of facial expression’ and recognition.

In the book *Thinking Like a Mountain: Towards a Council of All Beings* (Seed et al., 1988), Arne Næss writes in the essay *Self Realization: An ecological approach to being in the world*:

> Human nature is such that with sufficient all-sided maturity we cannot avoid “identifying” ourselves with all living beings, beautiful or ugly, big or small, sentient or not (Næss, 1988).

Thus, according to Næss, to identify ourselves with all living beings is a basic process. In the essay, he argues that in the “inescapable process of identification with others (…) the self is widened and deepened. We see our self in others” (Næss, 1988). Here, ‘the others’ means the larger community of all living beings. Næss introduces the concept of an ecological self to describe such a widened and deepened self. The students seem to recognize other living beings through such a basic process of identification. Following Næss, to see ourselves in others, including all living beings, give us a potential to develop a widened and deepened ecological self. To see ourselves in all living beings means that they are not solely objects for us to describe and systematize but living organisms with their own ways of being in the world. I argue that such an ability to imagine and immerse oneself in other beings is also present in Aristotle’s description of *eidos* (see section 11.1.1). To be able to describe not only an animal’s constitution, but also, the essence of an animal’s form and function as a whole, you would have to imagine how this animal lives and identify whatever is significant in its way of being.

Thus, both *what* the teacher pays attention to, and *how* the teacher invites the students to observe living nature, have ontological importance for the students. Entities in living nature are brought into existence for the students in these processes and provide the foundation for knowledge. However, a prerequisite for the teachers making this invitation, is that the things in living nature have become significant and recognizable to the teachers beforehand. When the students seem to look for ‘a facial expression’ in the earthworms and insects and see something more in living nature, they challenge the teachers’ experiences of ‘a lack of facial expression’ and their struggles to recognize the entities in living nature. These experiences indicate what may be fundamental different experiences of what the things in living nature are to teachers and students. Furthermore, the things in living nature we speak of are beings themselves. Recognizing other living beings by an emphatic engagement, instead of seeing them as objects for us to identify, point towards what I have called an ethical attention. I will return to this issue in Chapter 13, in Part five.

12.4.2 Practicing the skill of observation

Findings from both phases two and three demonstrate that practicing the skill of observation in school is complex, and that there are several answers to the question of what it means to be a good observer. When one of the teachers says that “you have to know what to look for, so you don't just look for anything that doesn't matter”, it demonstrates this teacher’s understanding of a way of knowing. The statement implies that to get knowledge that matters in an observation you have to know something beforehand and describes a deductive approach to practicing observation. In addition, the statement brings forward the essential and ethical question of who decides what matters in an observation. When one of the students says that “You should always look several times to catch all the details”, it seems to demonstrate another way of knowing. All students emphasized the importance of looking for details, observing several times and observing in nature, thereby describing a more inductive approach to practicing observation.

Knowledge may be seen as an organization or articulation of what the students perceive in living nature. How this articulation happens depends on what the students observe and what they perceive as being significant to observe, based on the context and earlier experiences, but also on their ability to express what they observe. In the following I will discuss three important issues that emerge from the findings in phases two and three, about how to practice the skill of observation as a way of knowing: 1) the interaction of skills in observation, 2) aesthetical and embodied learning processes, and 3) the questions of what matters in an observation.

The interaction of skills in observation

According to Ingold (2018), “all knowledge is founded in skill” (p. 11). Learning a skill may open a path to knowledge if the route is comprehensible and exists “within a field of associated tasks that are already partially familiar by virtue of earlier experience” (p. 11). A recipe, for instance, can give guidance, but can never explain everything you must do to bake a cake, there will always be gaps of information that must be filled. However, the more familiar “the field of associated tasks” is, the easier it will probably be to make the guidance meaningful. When it comes to practicing the skill of observation, teachers may offer guidance and show the students how to observe. However, the route to be followed must consist of partly familiar tasks that makes the process meaningful for the students.

According to both the teachers’ and the students’ experiences, there is an interaction of skills in observation, meaning that there are connections between several skills that influence and respond to each other. For instance, the way in which the students practice describing what they observe may change what becomes significant in the observation. Three of the teachers emphasize how drawing may change how the students observe, and one of the teachers says that his students have “to look more closely at what things really look like” when drawing (Tom, section 12.1.2). All the students, demonstrate a fine-tuned ability to notice details when they describe specimens or pictures of living organisms, and they also explicitly emphasize the importance of observing details to be a good observer. However, an important aspect, brought forward by two of the students’ descriptions of butterflies, is that the students have various preferences and abilities when it comes to *how to* describe what they observe (Emma and Sebastian, section 12.2.2).

Practicing observation of living nature within a familiar setting for the students, like collecting earthworms, looking for insects beneath rocks and logs, sitting in a tree, picking flowers, drawing, playing, and using their bodies as well as their minds, probably make the observational practices more meaningful to the students. When the students made dioramas showing the life cycle of butterflies, they seemed to practice the skill of observation within a field of associated tasks that was familiar to them. The tasks were inspired by Merian's holistic and aesthetical approach to observing living nature, and designed mainly by the teacher Lisa who is an art-teacher and also is a former pre-school teacher. However, drawing without using color-pencils and make quick sketches of butterflies by looking at photos presented on the screen in the classroom, seemed to be rather unfamiliar to most of the students. This task was designed by the teacher who is a science teacher. One of the students comments the sketching task like this: "It [sketching butterflies] was a lot of fun, but also a bit difficult because you couldn't include everything [in the drawing]", and she confirms that she would have liked to have drawn more carefully and include colors in the sketches (Emma, section 12.2.2). Using colors and more time in the drawing would probably have made the task more comprehensible to this student. Another student also struggles with the task and says that "the pencil doesn't go the way I want it to" (Sebastian, section 12.2.2). However, when the same student later draws a privet hawk moth in his notebook on his own initiative, he uses colors and makes a very characteristic and detailed drawing of this butterfly (Picture 7). Thus, the quick sketching task induced by the teacher seems to inhibit, rather than enhance, the students' ability to practice observation and describe what they observe.

Another finding from the interviews with the teachers is that they find it hard to distinguish especially between describing and explaining when discussing what it means to practice different skills with their students. The importance of distinguishing descriptions from explanations was already realized by Aristotle. He described the different kinds of observation in two books; in the *History of animals* he described animals form and anatomy (Aristotle, 1990a), and in the *Parts of animals* he explained why animals have certain form and anatomy (Aristotle, 1990b). When Aristotle explains his observations, he goes beyond what he can see directly. Similarly, one of the teachers says about describing an animal that "it could be an explanation if one explains the properties" and describes what she means as explaining the function of the different parts of an animal (Lisa, section 12.1.2). In practicing observation as a scientific practice, the difference between describing and explaining an observation, and also the order of these two activities, are essential aspects of scientific processes.

The teachers and students' experiences show that there is an interaction of skills in observational practices that is essential for the teachers to consider when they practice observation with their students. In addition, the teachers need to consider how to enable their students to respond to what they observe and express themselves in ways that are meaningful to them.

Aesthetical and embodied learning processes

From a body phenomenological perspective (cf. Merleau-Ponty), we are bodies entangled in the world, and experiences with living nature shape how we perceive the entities of living nature and how we perceive ourselves. When one of the students says: "If you are out looking at real plants, you get more than a picture, since then you can turn the plant around and look closely" (Elise, section 12.2.2), it demonstrates how it is possible for her to position herself and see the plants from more and different angles in nature, compared to observing a two-dimensional picture. According to Merleau-Ponty (2012), our body is the subject that observes, and the body observes as a living organism, not as a mechanism, formed by its environment and other conditions. Observation is a communication with the world, and never just pure impressions by the senses. Knowledge is generated in the process of practicing observation. In observation, our body seeks balance and stability if something seems blurred or undefined and will try to position itself in such a way that what is blurred or undefined presents more of itself (Merleau-Ponty, p. 315-316). For instance, by turning the plant around and looking closely, as the student puts it.

To understand the practice of observation in a body phenomenological perspective means that the students need to participate, not only with their minds, but with their whole body, to make meaning of what they observe. However, the classroom invites students to sit still on a chair at their desks, and most of the time classroom conditions address the students' minds rather than their bodies. The classroom seldom provides more than mere representations of living nature, such as pictures, films, models, and abstractions. Nature, on the other hand, seems to provide experiences for the students that appeal to their bodies and senses in a more immediate way. According to several of the students, they can see more when they observe in nature. The students also demonstrate in different ways how they use their senses in their observations of phenomena in nature: they like "the smell of nature" (Mia), they reaches out to touch the leaf and thinks it feels like a wet cloth (Peter), they perceives colors as important when drawing the butterflies (Emma), and they think both the flowers and the butterflies look "really nice" (Mia) (see section 12.2.1). One of the teachers says that students remember "colors better than the number of claws" (Victoria, section 12.1.2). The statement implies that the aesthetical qualities of living organisms may be easier for students to notice and remember than the quantitative features. Several of the students even highlight that being colorful is an essential characteristic with living nature. In addition, three of teachers emphasize the aesthetical qualities of butterflies as part of the success criteria in the implementation of the case of Merian, in terms of the students' engagement and interest. All these experiences underline the importance of aesthetic and embodied learning processes in practicing observation of living nature.

The question of what matters in an observation

Inspired by the philosophy of John Dewey, Ingold (2018) writes that "education is a practice of attention, not of transmission – it is through attention that knowledge is both generated and carried on." (p. 2). To be attentive comes from latin *attendere* and means to turn and stretch towards something.[27] Observing as a practice of attention may be what generates knowledge, rather than being told what to look for in an observation. Furthermore, one of the teachers says that the student should be involved in deciding what to look for in an observation (Thomas, section 12.1.2). The statement implies that the criteria for what matters are not given and that an important part of practicing observation may be for the students to discuss such criteria.

Findings from both the teachers' and the students' experiences suggest that living nature reveals new things if the students come back to observe the same phenomenon several times. One of the students says, "you look once more, and you see more" (Sebastian, section 12.2.2) and describes how one experience may lead towards new experiences. According to Dewey (1938), an educative experience is exactly that: an experience that enhances the learner's sensitivity and responsiveness and opens for the growth of further experience. Any experience has both longitudinal and lateral aspects (p. 43), which means that a

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[27] From Online Etymology Dictionary: https://www.etymonline.com/word/attend#etymonline_v_18908

certain experience is always part of a longer history (timeline) and a present environment that interact with each other. To educators, the challenge "is to select the kind of present experiences that live fruitfully and creatively in subsequent experiences" (Dewey, 1938, p. 28). When discussing what it means to practice observation, the teachers demonstrate a clearer emphasis after participating in the project, on creating conditions that enable the students to focus and notice new things through repeated observations, rather than telling them what to look for. The teachers' statements point towards a teaching that facilitates the students' experiences with the phenomena in living nature, in turn motivating further exploration.

On the other hand, "any experience is mis-educative that has the effect of arresting or distorting the growth of further experience" (Dewey, 1938, p. 25). To be told what to look for could constrain the students' sensitivity and responsiveness and have the effect of arresting further experiences. To be told what to look for in an observation means that the teacher decides what matters, at the same telling the students what is *not* significant. Furthermore, when the question of what matters in an observation is taken out of the hands of the students, the experience seems to lose an essential educative element. For instance, when one of the students says the butterfly has kind of stamens and looks like a flower (Sebastian, section 12.2.1), it could be easy as a teacher to reject the observation and say that it is not a relevant comparison. This would probably stop further explorations and give the student the impression that what they have noticed is not important or valuable. However, the student actually made a good observation and discovered how butterflies and flowers may be similar. The teacher could instead share the experience with the student and through dialogue try to stretch the student's attention, for instance, by letting them return to the phenomenon, and observing and comparing stamens and antennae in several flowers and butterflies. In the process the phenomenon would probably get increasingly richer to the student, and there could be a dialogue about what matters in an observation. Phenomena in living nature may continue to disclose new things to the students if they pay attention and come back to observe the same phenomenon several times and seem to open to experiences that motivate further exploration (cf. Dewey). What matters in an observation is not given and may change according to how teachers and students pay attention.

Thus, practicing the skill of observation may be understood as a way of knowing, and different observational practices may produce different ways of knowing. The students' experiences and statements about practicing the skill of observation seem to challenge the deductive approach to observation described by one of the teachers, where the students need to know what to look for. My findings suggest that an inductive approach may be more meaningful and comprehensible for the students. Practicing observation in school entails that the students: 1) practice associated skills that are (partly) familiar to them and that enable them to express themselves in meaningful ways, 2) apply embodied and aesthetical learning processes and respond to the aesthetical qualities with the phenomena in living nature, and 3) enhance their sensitivity and responsiveness by repeated experiences that motivate further exploration and that they are involved in deciding what matters in an observation.

12.4.3 The role of the teacher in observation

Findings from Phase 2, show that explaining plays an essential part when the teachers describe what they do when teaching. In Phase 3, the teachers seem to describe their role as teachers in somewhat contradictory terms and with a lack of a clear orientation. For instance, one of the teachers (Tom) says that "you want the students to see the same things as you do" when they practice observation, and he also says that it is important that the students are "asking their own questions and finding their own answers" (Tom, section 12.3.3). The students, in turn, would like the teachers to help them practice observation by letting them observe more in school, and one of the students says that "they [the teachers] have to observe a lot themselves to be able to show us how to do it" (Sebastian, section 12.2.3).

Communication is fundamental to all teaching. Biesta (2017) refers to Dewey who describes communication as participation and "a process where someone share experiences that become in common" (p. 51). Communication in this sense is not about a transmission of information, but a process that generates meaning and interpretation for those involved. For communication to work in this way, the quality of participation is important, it must be in the interest of all involved to participate (p. 64). To understand communication and teaching as participation, rather than as transmission of information, describes an alternative approach to teaching. However, in communication as participation, the outcome of the dialogue is open and not predetermined. The role of the teacher is at stake here. What does it mean to teach if it is not to explain?

One of the teachers says that as a teacher you “explain the world” to the students (Lisa, section 12.1.3). Another teacher reflects on the effect of explanation and says that explaining things (too soon) may stop the students’ own exploration (Victoria, section 12.1.3). Teaching understood as ‘explaining the world’ to the students points in a direction of teaching as a transmission of information, where teaching is a communication without participation for the involved students. Communication as participation (cf. Dewey), on the other hand, presupposes that the students and the teachers jointly engage in the activity of observation and find it meaningful. When the students say that the role of the teacher is to let them practice observation more in school, the students see the value of participating in observation and doing their own investigations. However, for the teachers to let the students do their own investigation is quite the opposite from explaining everything to the students and controlling the outcome.

An alternative to explaining, is for the teacher to facilitate experiences that let the phenomena in nature and knowledge of these come into being to the students. Facilitating for such experiences requires dialogue and communication as participation between teacher and students, and that the teacher directs the students’ attention towards some carefully selected phenomena and examples. Such an approach follows the genetic, Socratic and exemplary principles described by Wagenschein (2015). In regard to the teacher directing the students’ attention towards selected phenomena, Biesta (2022a) says “the basic gesture of teaching is that of trying to catch and direct the attention of another human being” (p. 2). When it comes to practicing the recognition of living nature, the role of the teacher may be to direct students’ attention towards both identifying and acknowledging living organisms (as elaborated in Chapter 6). However, the intention of such a process might not be to give definitive answers, but rather to make them see new things and look at things in a new way through exercises that stretch their attention. When one of the teachers says about the case of Merian that the students were “able to transform it [the task] into their own” (Lisa, section 12.3.2) it points towards a communication as participation where the students were invited to participate and contribute on their own terms.

Thus, the students saying that the role of the teacher in practicing the skill of observation is to let them participate in observational practices in school could be seen as a challenge to the teachers' understanding of teaching as explaining to the students. Understanding teaching as communication, and communication as participation, means to be in a dialogue with the students. The teachers cannot simply explain in terms of a transmission of information. The teachers must instead participate and engage in the practice of observing living nature to communicate with the students. However, to be able to direct the students' attention to selected phenomena in living nature, they will probably have to "observe a lot themselves to be able to show us [the students] how to do it" (Sebastian, section 12.2.3).

12.4.4 Observation as part of a scientific practice

Findings from Phase 2 show that when the teachers discuss what scientific observational practices are, their comments point in different directions. One of the teachers describes scientific observation in terms of "you must know enough to see what you see" (Thomas, section 12.1.4), while another teacher describes it in terms of "you don't always know what you are looking for" (Lisa, section 12.1.4*)*. The statements demonstrate some of the complexity in defining scientific practices. Findings from Phase 3 show that the students recognize some essential aspects of observational practices in science through the stories they are told about the four historical scientific pioneers, like observing carefully, taking notes, and creating systems.

Describing scientific practices is complex (e.g. Irzik & Nola, 2014). I do not expect teachers to accurately describe what observation as part of a scientific practice implies. However, some of the complexity emerges in the teachers' statements. Thomas's statement "you must know enough to see what you see" suggests that a scientific practice is deductive in the sense that you need knowledge beforehand to know what you see, or perhaps, to see what you are supposed to see. 'What you are supposed to see' can be understood as the laws in nature underlying the world as perceived by the. Thomas's statement seems to point to what has been called the ontological reversal in natural science, "meaning that abstract mathematical models of phenomena are taken as more real than phenomena themselves, as they appear in our everyday experience." (Dahlin, 2003, p. 77). Taken too far this understanding of a scientific practice may lead to a separation of the world we live in and the world of science, and thus to a lack of rooting (Roth, 2015; Østergaard, 2015).

Another teacher says that an open observation let "you notice things in a new way", but he does not find it very scientific, he even calls it "too hippie" (Tom, section 12.1.2). This statement also points to an understanding of scientific practices as being deductive. However, yet another teacher reflects over what the main characters in each of the four historical cases did when they investigated living nature and says, "you don't always know what you are looking for" (Lisa, section 12.1.4). Observing with an open mind to notice something in a new way seem to be at the core of what a scientific practice is or should be. However, the teachers' statements demonstrate that this is not obvious to them.

By exploring living nature with complementary modes of observations case-by-case, the students recognize some aspects of science. For instance, when the students talk about how Linné systematized living nature, the students say that systems make it easier to locate things and have things under control. At the same time, the students refer to their experiences with putting things in order, e.g., systematizing football cards, sorting color-pencils in their pencil case, or arranging clothes in their closet, to exemplify what it means to have a system. This demonstrates how the students intuitively connect the scientific practice of systematization to their lived experience and make it meaningful to themselves. However, the statements above may leave the impression of nature as something for humans to decode, categorize, and control. Such an approach might be problematic. Living organisms in nature may be perceived by the students as something fixed and delineated, like their color pencils or football cards. It is important to be aware of that the entities of living nature are living beings that are not fixed, they are rather dynamic, mobile, and growing. Due to the dynamic nature of living beings, categorization and classification in biology is different from categorization in other scientific disciplines (Reydon, 2013; Reydon & Kunz, 2019). Systematizing living beings is different from systematizing stones or metals, and experiencing this difference may be essential in observing living nature as part of a scientific practice.

When the students describe how Merian investigated butterflies, they emphasize different aspects of a scientific practice, like making multiple observations, caring for what you investigate, spending time observing and being patient.

These aspects of scientific practice are more in line with the following description by Ingold (2018): “There can be no science without observation, and no observation without the observer’s attention being closely attuned to those aspects of the world with which it is joined.” (p. 70). According to this statement, being “closely attuned” to the world we live in is the foundation for observation, and thus, science. Further, Ingold (2018) claims “we are curious because we care” (p. 71), and “research is the pursuit of truth through the practice of curiosity and care” (p. 72). Understood this way observation as part of a scientific practice is not an observation *of*, but rather an observation *with* or *from*: “Whereas of-ness is intentional, with-ness is attentional.” (p. 61).

When observing living nature as part of science education, these aspects might be vitally important to be aware of. Rather than understanding scientific practice as an observation of living nature, where knowledge, as predefined theories, concepts, and categories, keeps us at an arm’s length from the phenomena, scientific practice could also be understood as observation *with* nature. This would be a process in which we are led by curiosity and care, realizing that we are already immersed in living nature ourselves.

12.5 Conclusions and issues for further discussion

The phenomenological approach to discussing and understand the teachers and students’ experiences with observing living nature raises some issues for further discussion:

First, my findings show that the things in living nature are brought into existence for the students in observational practices. It means that the way in which the things are brought into existence for the students has an ontological meaning, and the things become of part of the students’ world (cf. Heidegger). However, the teachers and students may have different perceptions of what the things in living nature are, and these differences could challenge the process of practicing observation in school. In addition, the things in living nature are living beings themselves and this raise ethical concerns about *how* students get to know them. Observing at an arm’s length to systematize or explain living beings in nature does not justify the richness of these phenomena, neither in terms of understanding what living beings are, nor in terms of the students’ lived experiences. In teaching and learning, these findings imply that observing living nature consist of both existential and ethical practices. Understanding the practice of observing living nature as existential and ethical practice has implications for the role of the teacher. For the teachers, facilitating the students' experiences through a participatory dialogue and by directing the students' attention to selected examples and phenomena (cf. Dewey, Wagenschein, Biesta) may be an alternative to telling and explaining them what to look for. Such a teaching role implies that the teacher must pay close attention to both the students and the phenomena in living nature. However, stating that the role of the teacher is to direct the students' attention to some selected phenomena, raises new question about what such a direction entails and what it means to both the teacher, the students, and the phenomena in living nature. In Chapter 13, I will discuss these relationships further and explore the meaning of an *ethical attention* in teaching and learning observational practices *in* and *with* living nature.

Second, my findings show that practicing the skill of observation in teaching and learning in science is complex. While the teachers describe the practice mainly as a deductive process, the student describe practicing observation as a more inductive process. However, according to both the students and the teachers' experiences, practicing the skill of observing living nature implies that the students also practice associated skills, apply embodied and aesthetical learning processes, enhance their sensitivity and responsiveness by repeated experiences, and are involved in deciding what matters in an observation. These experiences imply that the students need to practice being attentive and responding to the phenomena in living nature in different ways to make them meaningful. In science education, observation is also a basis for scientific practices. My findings show that the teachers struggle to describe what scientific practices are, and their answers demonstrate some of the complexity in describing the processes of science. Practicing different modes of observation seems to expand and challenge the teachers and students' views about scientific practices. These findings lead to new question about what it means to practice the skill of observation in science education, such as: How can the inductive and deductive approaches in observational practices be balanced? How can embodied and aestethical learning processes in observational practices be integrated? How can the richness and complexity of scientific practices be portrayed in ways that are manageable and meaningful for teachers and students in primary school? In Chapter 14, I will discuss the above-mentioned questions and explore what more *sensible observational practices* may look like in primary school.

PART V: Discussion and implications

In Chapter 12, I examined different aspects of the teachers' and students' experiences with observing living nature. My findings suggest that observational practices that invite the students to pay attention and respond to what living nature presents to them, may be an alternative to teaching as telling the students what to look for. The criteria for what matter in an observation are not given, and the kind of skills the students practice may change their perception of what is relevant to observe.

In this part, I will discuss the connections between modes of observation in history, teaching, and learning that were presented in Part IV, and elaborate on some topics that are significant across the themes presented in Chapter 12. The discussion of themes demonstrates how observational practices not only have epistemological meanings, as ways of knowing, but also have an ontological meaning to both students and teachers. The things in living nature come into being through observational practices and constitute the world in which the teachers and the students live.

Two of the issues that seem significant in the discussion across the themes are *what* the teachers pay attention to in practicing observation with their students, and *how* the students are invited to observe the phenomena in living nature. These issues seem to have ethical implications for both the teachers and the students. In Chapter 13, I will explore these ethical considerations and discuss the meaning of ethical attention in observational practices. A preliminary version of this discussion has been presented by me before as a poster (Lien, 2022). A third issue that is brought forward in the discussion across the themes is the meaning of embodied and aesthetical experiences in observational practices. In Chapter 14, I will further discuss what more sensible observational practices may look like in primary school. Finally, in Chapter 15, I will discuss some implications of my work and reflect on my own process as a researcher in this project.

13 Ethical attention in observational practices

Ēthica (latin) - from ancient greek ēthikḗ, from ēthikós, "of or for morals, moral, expressing character", from êthos, "character, moral nature".[28]

Observo (latin) - I guard, keep watch over / I heed, regard, respect /I notice, perceive/ I observe, watch/ I pay attention to.[29]

In this chapter I will explore ethical attention as part of observing living nature in teaching and learning science. Observational practices in science education define what is important, valuable, and worthwhile to pay attention to. Observing living nature has ethical aspects concerning both *what* teachers bring into the students' field of perception, and *how* they invite the students to engage and participate with living nature.

Fredriksson and Panizza (2020) discuss ethical aspects of attention and the self. With reference to Iris Murdoch and Merleau-Ponty, they write that attention is "a foundational modality of consciousness through which the subject is able to engage with the world, and through which the world is disclosed to the subject; this both consists in and enables an ethical engagement" (p. 2). According to them, ethical attention is both an act of (active) self-suppression, which means an attention not distorted by self-concern, and an attitude of (passive) receptivity in which we are expectant of what the world presents to us.

According to Biesta (2021), an existential orientation to education entails "an act of (re)directing the attention of students to the world, so that they may encounter what the world is asking from them" (preface, p. vi). For the students to encounter what the world is asking from them, they must pay attention and engage as subjects with the world, and this process enables an ethical engagement according to Fredriksson and Panizza (2020). Thus, the ethical and existential aspects of paying attention seem to be closely connected.

[28] From Wiktorinary Free dictionary: https://en.wiktionary.org/wiki/ethica
[29] From Online Etymology Dictionary: https://etymologeek.com/lat/observo

Ethical attention in observational practices in science education entails, on the one hand, to promote the self of the student and acknowledge what is significant in his/her observation, and, on the other hand, to suppress the self-concern of the student and enhance his/her receptivity in an engagement with living nature. Recognizing living nature implies acknowledging and responding to other living beings, not merely identifying them (as is typical in science class). In the following, I will elaborate on these aspects, and explore the meaning of ethical attention for teachers and students in teaching and learning observational practices. I will start by discussing the differences and similarities between intention and attention in observational practices by comparing the four previously discussed cases from the history of science. I will further discuss the balance between these two orientations in science education.

13.1 Intention and/or attention in observational practices

The four historical cases in this study demonstrate different modes of observation in scientific inquiry. These observation modes represent what Jardine (2000) calls different “scenes of inquiry” in the history of science and relate to what has been perceived as relevant to observe in the exploration of living nature. In each of the cases, the central actor poses a different question about observing living nature that leads to different kinds of knowledge. However, when using these cases in science education, the notion of ethical attention in observational practices adds another aspect to these modes of observation that is existential rather than epistemological. The question is not only what kind of knowledge the students get when practicing different modes of observation, but how the things in living nature and the students come into being through these practices.

Ingold (2018) describes the distinction between intention and attention by using the example of going for a walk. Described in terms of intentions, the walker may be going for a walk, for instance, to improve his/ her fitness, or to see the countryside. The walker gets ready by planning the route and packing a map. In this account of going for a walk, “attention is the way the mind has of checking up on the world” (p. 25), like checking that the features in the landscape fit with those on the map. In another description of going for a walk, attention has another role: “The attentive walker tunes his movement to the terrain as it unfolds around him and beneath his feet, rather than having to stop at intervals to check up on it" (p. 25). Such an attentive walking calls for a responsiveness to the terrain, and to respond the walker must attend to the terrain as he/she goes along, joining and participating with his/her movement, and listen, watch, and feel. According to Ingold (2018),“to be open to the world we must surrender something of our agency. We must become responsive beings” (p. 23).

In the further discussion, I understand an orientation towards *attention* in teaching and learning observational practices as the teachers inviting the students to observe living nature in an open way that calls for their responsiveness and attentiveness. To respond to the phenomena in living nature, students must pay attention, join, and participate as subjects, and at the same time surrender some of their agency, and use their senses. I understand an orientation towards *intention* in teaching and learning observational practices, as the teachers telling the students to observe with a predefined aim of explaining and understanding the phenomena where the route is planned and there is a map to follow. The students only check if the landscape fits with the map, like checking if an insect has six legs, or a hoover fly has two wings. Such an intentional orientation to observation implies that the scientific explanations, theories, and/ or concepts come before making the observation. This primacy of concepts and theories may overshadow, reduce, or overemphasize certain aspects of the phenomena for the students, and possibly create diminished attention and care. Such an intentional orientation is related to a deductive approach to teaching which I will elaborate on in Chapter 14.

Ingold (2018) describes care as an aspect that “brings an ethical dimension to attention”, and “we care for people and things by giving them our full attention and by responding to their needs” (p. 27). The statement resonates with the notion of ethical attention described by Fredriksson and Panizza (2020). Responding to the world is foundational to an ethical attention, while understanding and explaining the phenomena as in an intentional orientation to observation are more like ‘checking up on the world’ to make account of persons and/ or things. The implication of Ingold’s argument to education is as follows:

> If education is about caring for the world we live in, and for its multiple human and non-human inhabitants, then it is not so much about understanding them as it is about restoring them to presence, so that we can attend and respond to what they have to say (Ingold, 2018, p. 28).

The phenomena in living nature are not only something to be explained or discussed in the science classroom, but something to be made present and restored to the students' attention. This is in line with a world-centered education that directs the students attention to the world (Biesta, 2021). Studies have documented an accelerated loss of nature and species (e.g. Ceballos et al., 2020; Gilbert, 2016; Hallmann et al., 2017) and a parallel loss of knowledge and a widespread blindness to plants and animals (Allen, 2003; Jose et al., 2019; Knapp, 2019; Schussler & Olzak, 2008; Thomas et al., 2022). Thus, practicing observation towards living nature is an ethical question about how students learn to care for and acknowledge the diversity of living beings in nature. Overcoming the blindness towards nature is essential to a sustainable education and practice (Thomas et al., 2022).

In the following, I will argue that used in the classroom, case I Aristotle and case II Merian may demonstrate an orientation towards attention in observational practices. Furthermore, that case III Linné and case IV Wallace and Darwin may demonstrate an orientation towards intention in observational practices. In Figure 12, I have placed the four different modes of observation along an axis of intentional/ attentional orientation.

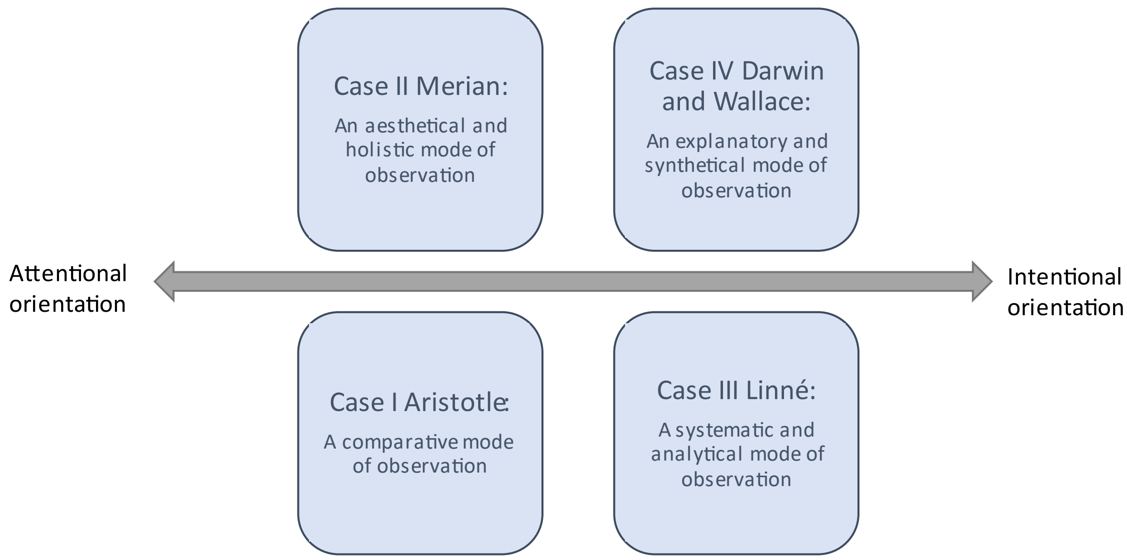

Figure 12: The four modes of observation demonstrated in the four historical cases, placed along an axis of intentional/ attentional orientation to observation.

13.1.1 Intentional orientation to observational practices

In a systematic and analytical mode of observation (cf. case III Linné), living organisms become discrete and bounded entities to be ordered and arranged in a system. The presupposition is that there exists a natural system of living organisms in nature, and the methodological commitment is to make observation based on quantitative analysis (Table 8). Used in the classroom, the orientation to observation is international in this mode because the students observe in order to systematize living organisms. The students need knowledge of a system beforehand, for instance, to systematize plants they need knowledge of the different parts of the flower and fruit. In this mode, the students observe to see if an observation fit with the system, and it is already decided what is significant in the observation. In classification, living organisms are sorted by what Linné called “certain and real” features, such as “number, shape, situation, and proportion” of the different parts of the flower and fruit (Müller-Wille & Reeds, 2007, p. 569). The features of living organisms that are possible to classify by, are the features that become significant. Features like taste, smell, or color, are seen as vague and uncertain, and thus become less significant in this mode of observation. Following from this, plants are described schematically, mainly by their shape and numbers of petals, sepals, stamens, and pistils. Such schematical descriptions of flowers have led to the general and abstracted models of flowers that are found in floras and in many textbooks (Figure 13). To the students, such schematical descriptions and models are very different from what they experience when they see a flower in nature. Such generalized descriptions are reductive and overemphasize certain aspects with the phenomena and may create a lack of rooting of the scientific concepts in the students’ everyday life (Dahlin, 2001; Roth, 2015; Østergaard, 2017).

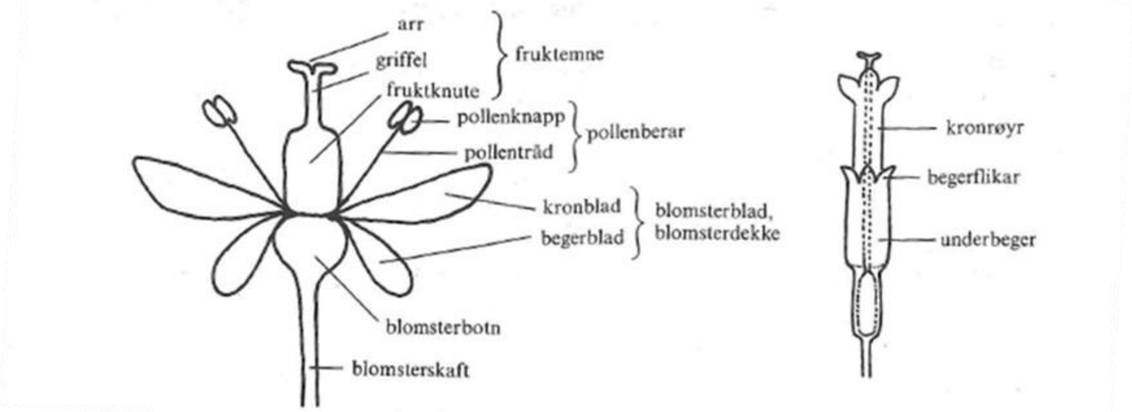

Figure 13: The parts of a flower. From Lid's Norwegian flora (Lid & Lid, 1994).

In an explanatory and synthetical mode of observation (cf. case IV Darwin and Wallace), observations of living organisms become something to explain. The presupposition is that living organisms are interconnected and part of a long history of evolution, and the methodological commitment is to provide a theory based on observations that explain the diversity of species (Table 8). Used in the classroom, the orientation to observation is intentional in this mode because the students observe in order to explain the living organisms. The students need knowledge of (or have ideas of) a theory beforehand to make such explanations and they observe to see if the observations fit with the theory.

Wallace's and Darwin's idea of a theory was based on and confirmed by their own observations, but also based on theoretical knowledge that they had beforehand. The high explanatory value of the theory of evolution is what gives the theory its strength. Once the overarching theory of evolution was formulated, Wallace and Darwin managed to explain multiple other observations from around the world. However, to the students, practicing to make such scientific explanations is a demanding task (Herman et al., 2013; Herman et al., 2019), and in school the explanation is more often provided by the teachers in a final form together with some examples that fit with the theory (e.g. Clough, 2007; McNeill & Berland, 2017). Without having a real opportunity to first practice attention towards the phenomena in living nature, the students will neither have the opportunity to practice how to generalize and make abstractions out of these observations, nor to understand what theories are (c.f. Wagenschein, 2015, p. 157). To simply give the students such an explanation may also stop the students' own explorations. According to one of the teachers: "maybe one should have waited even longer with the explanation, spend more time on the actual process of observation and description (…) It is a large part of science (…), the process itself, but there is also a lot of learning in it, the motivation to find the explanation" (Victoria, section 12.1.3).

Used in the classroom and with the notion of ethical attention in mind, the cases of Wallace/Darwin's and Linné seem to demonstrate an intentional orientation to observation. In both cases, there is an observation *of* nature in order to systematize or explain the phenomena students observe. If only these two modes of observation are used in science teaching, the students do not really get a chance to respond to and connect with the phenomena they observe because what is significant in the observations is already decided and the observations already has an explanation. All the teachers in my study, in different ways, express that teaching means to explain and one of them even say that “being a teacher is to explain”[30]. These statements seem to align with an intentional orientation to observation. However, the picture is not unambiguous, as demonstrated with Victoria’s quote above about waiting with the explanation and spending more time on the process observation.

To the students, as found in the interviews, colors in living nature and other features that appeal to their senses are essential for how they perceive these phenomena. If only features like the ones Linné called “certain and real” are considered significant, or if observing to find specific characteristics to classify insects are always preferred to an open observation[31], the phenomena are in danger of becoming less rich to the students. When two of the students describe butterflies either orally or in drawing, colors are important in their descriptions, for instance, one of them says: “So, on the peacock butterfly, it's important to note that it's quite red on the wings and a bit browner down here on the other two wings. Then it kind of has eyes on the wings, and then it's a bit of white around the wing” (Sebastian, section 12.2.2). Another student says that he reached out to touch a wet leaf and: “It was a bit wet too, then it [the leaf] becomes like a cloth” (Peter, section 12.2.1). Yet another student talks about the smell in nature and that she “really likes sitting in nature” (Mia, section 12.2.1). To be told that features in nature that first and foremost appeal to their senses, like touch, smell, and colors, are not significant, could reduce their experience of the phenomena and create a distance to the students’ lived experience with plants and animals. This seemed to be happening when one of the teachers told the students to make quick sketches of butterflies without using their color pencils. One of the students said about the exercise: “It was a bit difficult because you couldn’t include everything [in the drawing]” and she confirms that she would have liked to use colors and have more time (Emma, section 12.2.2). Likewise, to give the students an explanation without first giving them sufficient experiences with

[30] Elaborated in Theme 3: “Being a teacher is to explain” (See section 12.1.3)
[31] In the interview with Tom, he expresses that he does not find an open observation to be very scientific and I ask him whether there are other approaches that he prefers, Tom answers: “Yes, when we studied insects. Because you learn about insects and the characteristics, and then you learn to recognize those characteristics, and you get to study it, so you can sort of classify more easily because then you know you what to look for too”.

observing the phenomena themselves, could create an impression that the explanation behind the observations is more significant than the nature observations themselves and lead to an ontological reversal (Dahlin, 2003).

Although students need to practice systematizing and explaining observations in living nature as part of a scientific practice, my findings suggest that there is a tendency towards generalizing and theorizing observations in school. To be able to recognize other living beings, by both identifying and acknowledging them, the students need to practice more than an intentional orientation to observation.

13.1.2 Attentional orientation to observational practices

In a comparative mode of observation (cf. case I Aristotle), living organisms become entities with unique ways of being in the world. The presupposition is that different living organisms have an innate essence (*eidos*) defined by the unique form and function of its different parts, and the methodological commitment is to make observations based on comparison of different living beings (Table 8). Used in the classroom, the orientation to observation is attentional in this mode because the students don't need theoretical knowledge about what they are observing beforehand and because they must pay attention and respond. The students sort animals into groups that seem intuitive like birds, fishes, or insects, and then they compare different parts systematically, looking at several characters at the same time. To find what characters are significant, the students must pay attention to how the forms and function of different parts serve the organism as a whole and what is important in this organism's way of being in the world. Using this mode of observation, the students practice elements of both systematizing and explaining observations of living organisms, but there is no predefined system or explanation, and science is not presented in a final form (Clough, 2007; McNeill & Berland, 2017). The aim is to find what is unique about a particular animal. Aristotle expresses that "the true method is to state what the definitive characters are that distinguish the animal as a whole; to explain what it is, in both substance and form" (p. 163, 641a). The underlying question in finding what is unique about a particular animal and "explain what it is in both substance and form", is: What is it like to be this animal? In education, this question invites the students to pay attention and emotionally engage with the living organisms they observe (Lanouette, 2022). In the classroom, while observing earthworms in a terrarium, the students asked questions like: "How do they sense [their environment]?” and “How do they pee?” (Notes 29.10). Such questions indicate that it is rather intuitive for the students trying to imagine what it is like to be an animal, and the students seem to emotionally engage with the earthworms. The question “How do earthworms sense their environment?” could be a very good starting point to further explore connections between the form and function of parts in this animal, and the earthworm’s unique way of being.

In an aesthetical and holistic mode of observation (cf. Merian), living organisms are described also by their aesthetical qualities and how they are part of a larger context. The presupposition is that living organisms can be described according to their dynamic and interconnected nature, and the methodological commitment is to make observations to provide accurate and holistic descriptions (Table 8). Used in the classroom, the orientation to observation is attentional in this mode because the students must use all their senses to observe carefully and to describe details and complexity. Furthermore, they don’t need knowledge of classification or theories beforehand. In this mode of observation, the aim is to describe living organisms according to their nature by using an aesthetic attention. The living organisms, or the butterflies in this case, are not divided into parts to be categorized or explained, but are richly described as colorful, dynamic, and interconnected beings. In many instances, the butterflies don’t even have a name in Merian’s descriptions. Using this mode of observation in teaching, the students are invited to aesthetic experiences and embodied forms of learning in both observing and describing living organisms (Dewey, 2005; Fredriksen, 2020; Pugh & Girod, 2007; Østergaard, 2015, 2017). In this mode of observation, the students get a chance to respond to the aesthetical qualities in living nature and use their fine-tuned ability to observe details. The implementation of the case of Merian in school showed that the butterflies, as colorful, transforming, and entangled phenomena, appealed to the students. In creating their own models of the butterflies’ life cycle, the students were able to observe carefully and describe both details and complexity.

In science education, with the notion of ethical attention in mind, Aristotle’s and Merian’s modes of observation seem to demonstrate an observation *with* nature that brings attention to each individual phenomenon in its unique living environment. For instance, comparing form and function of legs and wings of different species of insects like Aristotle bring attention to individual insects and their unique way of living. In using these two modes of observation in science education, the students must engage in, and respond to, what they observe, either by finding what is unique about a certain organism in a comparative mode of observation, or by providing their own detailed descriptions of what they observe in an aesthetical and holistic mode of observation. Rather than reducing the phenomena and creating a distance between observational practices and the students' lived experience, these modes of observation can enhance the students' receptivity towards living nature.

13.1.3 Strengths and constraints of intentional vs. attentional orientation

One of the teachers in this study says that "you have to know what to look for, so you don't just look for anything that doesn't matter" (Lisa, section 12.1.2), and all the teachers, in different ways, express that teaching means to explain. With these statements, although they are not unambiguous, the teachers seem to exemplify an orientation towards intention in their science teaching, and emphasize a primacy of cognition rather than of perception (Dahlin, 2001). With the notion of ethical attention in mind, there seems to be a need to balance this tendency towards cognition and intention with a stronger emphasis on attentiveness in observational practices in science teaching and learning. However, having argued for an attentional orientation to observation above, an intentional orientation to observations still has an evident place in science education. The questions are rather how these orientations to observation might complement each other, and what the order of these orientations in teaching and learning is, i.e., which one of them comes first?

The *strengths* of an intentional orientation to observation of living nature are, for instance, that students can use precise names and systematize their observations based on a predefined system of classification. Further, the students can use the theory of evolution to connect and explain multiple observations, and they can explain new observations within the perspective of this theory. Concepts, systems, and theories that make sense to the students (Berland et al., 2016) serve to make observations in nature manageable and understandable, and may also enhance the students' observational skills. A *constraint* with an intentional orientation to observation in teaching and learning is that the quantitative features of living organisms seem to be overemphasized in making classification systems. Another constraint is that theories and concepts may appear to have a higher ontological status than the students' lived experience and enhance an alienation towards the phenomena in living nature as the students experience them (Dahlin, 2003; Roth, 2015; Østergaard, 2015, 2017). In addition, a one-sided focus on theorized and abstracted models and concepts possibly makes it more difficult to recognizing plants and animals *in* nature.

The *strengths* of an attentional orientation to observation of living nature are that it may promote the students' connection with the phenomena in living nature and their ability to recognize and relate to plants and animals in nature, and promote sense experiences and aesthetical learning processes (Dewey, 2005; Fredriksen, 2020; Pugh & Girod, 2007; Østergaard, 2015, 2017). An attentive approach lets the phenomena in living nature present themselves and "speak" to the students without predefined theories and systems, thus giving room to discover unexpected phenomena, but also an occasion to practice how to systematize observations and make abstractions. The *constraints* with an attentional orientation to observation in teaching and learning are that it may be difficult for the students to describe and keep track of many observations due to a lack of precise names and a predefined system of classification. In addition, the students miss opportunities to explain and connect multiple observations with an overarching system and a general theory. A lack of predefined concepts, systems, and theories may lead to the students overlooking and missing important aspects of the phenomena they are investigating.

In Table 14, I summarize strengths and constraints of having an orientation towards either intention or attention when observing living nature. I will argue that it is necessary to balance and complement these orientations with each other and alternate between them in teaching and learning science. What seems to be a tendency towards an intentional orientation to observation in which students are merely "checking up on the world" (cf. Ingold), needs to be balanced by observational practices where the students attend and respond to phenomena. For the teacher it is important to consider the order of having an orientation towards either intention or attention in observational practices. To make the conceptual knowledge meaningful to the students, the teacher needs to facilitate for students connecting with the phenomena in nature through attentive observational practices.

Table 14: Strengths and constraints with having an orientation towards either intention or attention when observing living nature.

	Attentional orientation	Intentional orientation
Strengths	• promote the students' connection with the phenomena in living nature (promote rooting) • promote the students' ability to recognize and respond to plants and animals in nature. • promote sensory experiences. • let the phenomena in living nature present themselves and "speak" to the students (without predefined theories and systems) • give room to discover unexpected phenomena. • give occasion to practice how to systematize observations and make abstractions	• make it possible to systematize observations based on a predefined system of classification and precise nomenclature. • explain and connect multiple observations with a general theory. • make it possible to explain new observations (within the perspective of a certain theory)
Constraints	• lack of an overall system or classification makes it more difficult to keep track of many observations. • lack of predefined concepts to describe observations. • Lack of predefined theories to explain observations	• overemphasize quantitative features of living organisms that can be counted and measured. • may enhance an alienation towards the phenomena in living nature as the students experience them (lack of rooting) • make it more difficult to recognize plants and animals *in* nature

I will argue that to recognize living beings in nature, as both identifying and acknowledging them, the students need to practice an *ethical attention*. In the next sections, I will discuss the meaning of an ethical attention in teaching and learning.

13.2 Teaching and learning with ethical attention

The act of teaching entails ethical considerations about *what* the teacher bring attention to, and *how* the students are invited to respond to the phenomena in the world. Thus, the question of ethical attention in observational practices applies to three relationships: between the teacher and the students, between the teacher and phenomena in living nature, and between the students and the phenomena in living nature (Figure 14). In the following, I will discuss 1) the role of the teacher in this triangle of ethical attention, 2) what it means for students to practice ethical attention in observation, and 3) how the phenomena in living nature invite teachers and students to pay attention to them. I will explore the conditions for ethical attention in these relationships.

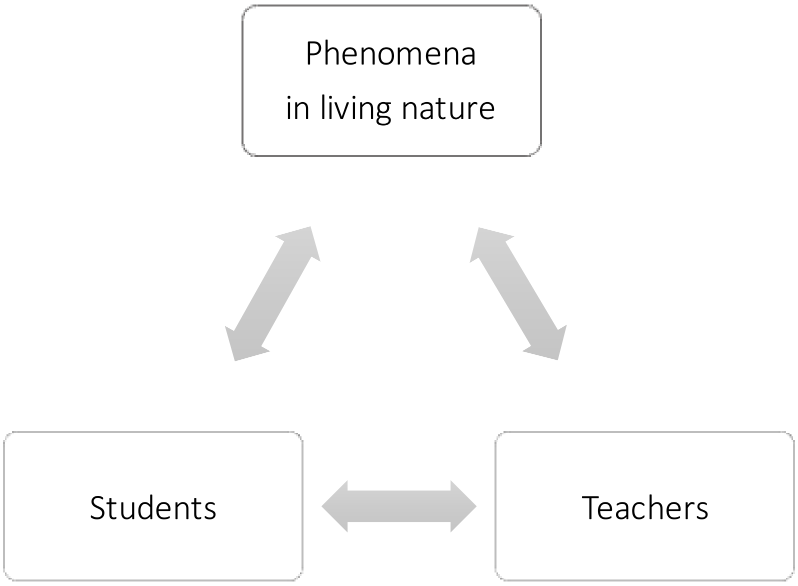

Figure 14: Ethical attention applies to the three-part relationship between teacher, students, and the phenomena in living nature.

13.2.1 Teaching with ethical attention

> Thomas (teacher): “I think that observation may create wonder and fascination for life in a way (…) In wonder there are questions, by observing one can jointly come up with questions that are exciting to work on. However, it is difficult to make good questions (…) Observation is important in that way I think.”

In the statement above, Thomas says that observation create wonder and questions in the students, which could be another way of saying that the students “encounter what the world is asking from them” in an attentive observation (Biesta, 2021). Thomas also says that “one can jointly come up with questions that are exciting to work on”, which implies that with such an approach he can participate in a dialogue with the students about what they are going to explore and how they are going to respond to the phenomena they observe. Thomas describes how practicing (an attentive) observation directs the students to the world, and how the teacher in this act may acknowledge the students. What seems to be missing in the quote are the phenomena in living nature. I will argue that the main condition for teaching with ethical attention is:

(i) *The teachers acknowledge the students as subjects and at the same time overcome their own blindness towards the phenomena in living nature.*

To be able to see how the teachers can silence themselves and be receptive towards both the students and the phenomena in nature, it is necessary to describe the act of teaching first. With reference to Klaus Prange's work on how education is enacted, Biesta (2022b) argues that the basic gesture of teaching is that of pointing. Pointing has a double meaning of pointing *at something* and referring *to someone,* and it both focuses the attention and asks for attention. Pointing is an evocative gesture that calls out for someone's attention and response, and "this gives pointing its educational significance", according to (Biesta, 2022b, p. 20). An educational pointing requires double (ethical) attention to the phenomena pointed at by the teacher, and to the students the teacher refers the pointing to (c.f. Østergaard, 2011). There is a "morality of pointing" and the three key-requirements to good educational pointing is that it needs to be: "understandable ('verständlich'), appropriate ('zumutbar'), and connectable ('anschlussfähig')" for the students (Biesta, 2022b, p. 26). These requirements are not ethically neutral, they entail the demand of truth, respect, and freedom (p. 27).

Referring the pointing *to someone* and acknowledging the students as subjects in the act of teaching, means that the teacher points to phenomena in living nature that are: 1) understandable and can be grasped by the students, 2) appropriate and accessible to the students, 3) connectable with the students' lives and interests and something the students can respond to. In other words, a condition for teaching with ethical attention is to consider the students as subjects and use a gesture of pointing that build on truth, respect, and freedom. To be able to refer the pointing to someone, the teacher must be receptive and expectant to the students' experiences with the living beings in nature, and in this lies the teacher's ethical attention towards the students. The teacher must silence him-/ herself, 'tune-in', and turn his/her attention to the students, not only to get the students' attention, but also to call out for the students' response. When Thomas says that observation creates wonder and "by observing one can jointly come up with questions" in the above quote, he demonstrates how he is receptive and expectant to the students' experiences with observing the phenomena in living nature and calls for their response to "come up with good questions".

What comes out of teaching as pointing, both in terms of anticipations, knowledge, practice, and emotions (Lanouette, 2022), will depend on the students' former experiences and what they perceive as significant in the concrete context. According to Biesta (2022b), students respond to the teachers pointing "in a reflexive way, that is, with reference to themselves, and not in a purely reactive or mechanistic way" (p. 24). In other words, the students' perception and their response to the phenomena they observe in living nature depend on their lived experiences and on their body as the subjective that observes (cf. Merleau-Ponty). The result of such an observation is open and undecided.

To be able to point *at something* and call for the students' attention and response to the phenomena in living nature, the teachers need to recognize and acknowledge these phenomena themselves. As one of the students in this study expresses: "The teachers have to observe a lot themselves to be able to show us how to do it" (Sebastian, section 12.2.3). My findings suggest that the teachers lack some experience with observation and recognizing the living beings in nature and express an uncertainty about their role as teacher in practicing the skill of observation with their students (as discussed in section 12.3.3). The teachers in my study seem to be affected by the reported overall blindness to nature (Jose et al., 2019; Thomas et al., 2022; Wandersee & Schussler, 1999). Furthermore, they might be affected by a science teaching that focuses on concepts and theories and that is partly blind to the living phenomena the teaching is about (Dahlin, 2001, 2003).

However, two of the teachers in my study express important lived experiences with the phenomena in living nature that could be used as a starting point for practicing the skill of recognizing living organisms in nature with their students. One of them struggle to describe what a species is: "If they look the same, maybe it's the same species, then you suddenly find out that these oak trees are not the same species, because one is summer oak and one is winter oak. So, then the question is how small the differences can be for it to be two different species" (Tom, section 12.1.1). Another teacher says about nature: "It is so big that we cannot imagine it. It's kind of endless. A bit like when you dive, you constantly see something new, and then you see something, and then you see something new. You just see right in front of you, and then when you come back you see something else” (Lisa, section 12.1.1). Both these statements, coming from the teachers’ own lived experience, reflect important aspects of recognizing the phenomena in living nature. The phenomena can be difficult to delineate, and observing these phenomena in nature may lead to constantly new experiences and further exploration. For the teachers, pointing at both these aspects with the phenomena in living nature could be a good way to call for the students’ attention and response. For instance, pointing at the two species of oak trees and other similar phenomena in nature, and let the students observe and discuss the differences between them, and how small the differences can be for them to be two different species, is a good way to call for the students’ attention to the phenomena in living nature. Another way to call for the students’ attention, could be to use the other example put forward by Tom in the same statement and point at two ducks that look very different and discuss with the students why they nevertheless are the same species. Likewise, urging the students to come back to observing the same phenomena several times and let them experience that when they do so, they might notice new varieties and new features with the living beings in nature, could be essential in practicing observation. These examples demonstrate the importance of the teachers having experience with observing living nature themselves. For the teachers, to be able to call for the student attention and response, they must first recognize such phenomena in nature, and in addition, they must acknowledge these experiences as important in teaching and learning.

Thus, the primary condition for the teachers to be able to point *at something* that is worthwhile for the students to pay attention to in living nature, is that they overcome their own blindness by practicing observation and gaining experience with the phenomena in living nature. The teachers need to balance an intentional orientation to observation, that mainly explains or understands phenomena, with an attentional orientation to observation that invites the students to connect and respond to what they observe.

13.2.2 For students to practice ethical attention in observation

> Peter (student): “It’s a bit difficult [to be a good observer] … If you're going to get some things to come close to you, for example a bird, then you must sit completely still, if you make noise, you might scare it away.”

To practice an ethical attention towards living nature, students must enhance their receptivity in an engagement with living nature and at the same time suppress their self-concern. I will argue that Peter demonstrates what ethical attention might entail with his description of observing a living bird in nature. Peter describes a situation in which he suppresses his self-concern by sitting still and being quiet, and where he is receptive to the bird’s needs and to what might scare it. He responds to the bird and silence himself to let the bird show itself. I will argue that the condition for students to practice an ethical attention is:

(ii) *The students practice responding to and relating themselves to other living beings, rather than just identifying them.*

Suppressing self-concern

To pay attention in a conversation with another person, you will have to silence your own thoughts and worries, and listen with care to what the other person says (Fredriksson & Panizza, 2020). For the students, positioning themselves in the world and letting the phenomena in living nature present more of themselves (cf. Merleau-Ponty) and come into being (cf. Heidegger) may require silencing themselves and sitting completely still.

Suppressing self-concern in encounters with the phenomena in living nature does not mean that the students suppress their selves, it is rather a condition of “unselfing” where “the self either disappears or drops into the background for attention to reveal the world” (Fredriksson & Panizza, 2020, p. 4). This can be done directly by being less self-absorbed, or indirectly, by not allowing the self to distort their perception of the world (p. 5). Biesta (2021) argues for a world-centered education and claims:

> To exist as subject “in” and “with” the world is about acknowledging that the world, natural and social, puts limits and limitations on what we can desire from it and can do with it – which is both the question of democracy and the question of ecology (p. 3).

When observing living nature, it is not only a question of how the students can make sense of or understand those phenomena ('what is the world for me'), but what the phenomena are asking of the students. Like when a living bird restrict how a student can act if the student wish to observe the bird. Sitting completely still to observe a bird, the student might experience an unselfing where the self is absorbed with this phenomenon in nature, rather than being absorbed with itself. Furthermore, my findings show that there is a potential for such an experience to create new questions in the students, like: What is it like to be a bird? How does it sense its environment? What does it eat? What does it need? Such questions relate to questions of ecology and invite the students to reflect on how the living beings in nature restrict what the students can desire from them and do with them (cf. Biesta above).

To practice suppressing their self-concern the students must silence themselves and let their self drop into the background to reveal the phenomena in living nature.

Being receptive

For the students to recognize other living beings by identifying themselves with them, and not just identifying them, implies recognizing an identity, or a "face", in nature. For human beings, detecting, recognizing, and interpreting human faces are highly important skills, and we may infer emotional states, intentions, and attention in facial expressions. While one of the teachers in my study experiences a "lack of facial expression in nature" (Thomas, section 12.1.1), the students seem to look for a facial expression when they observe insects and earthworms. Still, several of the students hesitate when I ask them whether plants are alive or not, although all students conclude that they are. The students perceive degrees of being alive; for instance, butterflies are seen as being more alive than plants. Mia says: "Butterflies are in a way a bit more alive, but plants are also very alive", and she seems to think that the butterflies are more alive because they change more, and their life cycles are more complicated (Mia, section 12.2.1). The students' perception of there being degrees of being alive indicates that the students might experience a degree of recognition, or identification, with different types of organisms. Plants are more difficult for the students to recognize than animals, in line with several studies about plant blindness (e.g. Allen, 2003; Balas & Momsen, 2014; Buck et al., 2019; Ebert-May & Holt, 2014; Knapp, 2019).

The students need to practice an attentive observation to notice the living and complex dynamics of both plants and animals, and that may promote more “holistic and just” relations with living nature (Lanouette, 2022, p. 612). Recognizing and classifying living beings is different from classifying non-living phenomena in nature (Chambers, 2012; Nyléhn & Ødegaard, 2018), and unambiguous causal explanations have often been demonstrated to be inappropriate for biological phenomena (Herman et al., 2019). Living organisms are part of complex systems and there may be multiple causal explanations for phenomenon, and unpredictable factors may emerge in the exploration (Mayr, 1982; Morante & Rossi, 2016). To recognize living organisms in a just way, the students need to practice a classification that is more dynamic and has less emphasis on decontextualized approaches (Lanouette, 2022).

Being receptive to the phenomena in living nature implies that students practice an attention that is “closely attuned” to those phenomena (cf. Ingold, 2018, p. 70). My findings show that the students have a fine-tuned ability to pay attention to details of the phenomena they observe, they respond to the aesthetic qualities in living nature, and they have an ability to identify themselves with the living beings in nature. These findings indicate a potential for the students to be receptive and closely attuned to the phenomena in living nature. However, the students need to practice observation that allows the living and complex dynamics of both plants and animals to come forward.

Being responsive

Responding to the phenomena in living nature is crucial to an ethical attention. Paying attention and responding to a bird, or an earthworm, or a plant, can be seen as a way of caring for them (cf. Ingold, 2018). Being responsive means that the students need to be in some sort of dialogue with the observed phenomena. One of the students in my study says that she sees more of a plant if she can observe a living plant in nature, because than she can “turn it around and look closely” (Elise, section 12.2.2). The student positions herself so the plant can show itself, in much the same way as the before-mentioned student positions himself sitting completely still to let the bird show itself. For the students to position themselves like this, according to the living beings *in* nature, is a way of being in a dialogue with and responding to them.

The students can practice responding to the phenomena in living nature by expressing what they observe. However, students need to express themselves in ways that are meaningful to them, or in other words, in ways that are understandable, appropriate, and connectable for them (Biesta, 2022b, p. 26). My findings suggest that the phenomena in living nature are brought to the foreground in different ways according to how the students practice expressing what they observe. For instance, both the teachers and the students say that drawing a plant or an animal affects the observation and can make the students look closer and see the phenomenon clearer. One of the teachers also expresses that the students remember better what they have drawn, and that they "remember colors better than the number of claws" (Victoria, section 12.1.2). These findings are supported by research that demonstrate that drawing enhances the memory (Wammes et al., 2015), activates the brain in a way that is positive for learning (van der Meer & van der Weel, 2017), and affects what and how the students observe in science learning (Fan, 2015; Wu & Rau, 2019). However, my findings also show that for some students drawing might be a hindrance for expressing what they observe, and they would rather express what they observe in words. These findings indicate that drawing might be essential for some students in practicing observation, and at the same time, that the students need several options to be able respond to and express what they observe.

To practice being responsive means that the students are in a dialogue with the phenomena in living nature, and that they are given the opportunity to express what they observe in ways that are meaningful to them.

13.2.3 How do living beings in nature invite us to pay attention?

> John (teacher): [the meaning if observation] is to get to the basis in a way, that it is not just their [the students] own opinions and views, but that they go in and look at it [nature] quite concrete and what it actually is.

> Lisa (teacher): What stayed with me is that it is like nature (…) is so big that we cannot imagine it. It's kind of endless. A bit like when you dive, you constantly see something new, and then you see something, and then

> you see something new. You just see right in front of you, and then when you come back you see something else. So there ..., that stays with me. There is always something more behind what we see.
>
> Elise (student): That animals have more colors (…) because a stone is just gray, and then just a shape, or other different colors, while a butterfly has sort of different patterns, different shape (…) there are wings, and there is a body where they are attached. There is much more to a butterfly than a stone.

The quote from John says that observation gives the students the opportunity to study nature to see "what it actually is", and that "it is not just their own opinions and views". His statement has ontological implications: there is a world that give access to things that exist, and this world is something more than the students' views about things that exists. In other words, there is a world to be disclosed. The quotes from Lisa and Elise above, demonstrate how the living beings in nature seem to invite us to pay attention. Living nature invites to endless discoveries according to Lisa, or in other words, the phenomena in living nature seem to ask from us to be disclosed. In addition, Elise's quote indicates that the living beings in nature appeal to our senses and request an aesthetical engagement. I will argue that the condition for living nature to be attended to is:

(iii) *The phenomena in living nature can be disclosed and invite teachers and students to pay attention to them.*

Knowing the world is part of the primordial being in the world (cf. Heidegger). Other living beings are part of our environment, as we are part of theirs. All living beings, humans included, learn through their bodies and in relation to the affordances of the environment. (Fredriksen, 2020; Gibson, 2014). Affordance is a term first used by Gibson (2014) to describe what an environment offers or furnish a living being, and I will return to Gibson's concept of affordances in Chapter 14. Depending on how we pay attention and respond, an environment of living nature invites to manifold discoveries. The phenomena in living nature are disclosed through activity and by interacting with them, for example by sitting still to let a bird show itself or turning a plant around and look at it closely. However, if teachers and students do not pay attention by using their senses, and do not practice letting the phenomena show themselves, the phenomena in living nature will probably not be disclosed to them.

13.3 Conclusions

Ethical attention in observational practices applies to three relationships: between the teacher and the student, between the teacher and phenomenon in living nature, and between the student and the phenomenon in living nature (Figure 14). In this section, I have argued that there are three conditions for ethical attention in this three-way relationship:

(i) The teachers acknowledge the students as subjects and at the same time overcomes their own blindness towards the phenomena in living nature.
(ii) The students practice responding to and identifying themselves with other living beings, rather than just identifying them.
(iii) The phenomena in living nature can be disclosed and invite teachers and students to pay attention to them.

Observational practices that enhance the students' receptivity towards living nature, decrease their self-concern when engaging with living beings in nature, and call for their response, are in line with an ethical attention in science education. Observing with a combination of attentional and intentional orientation, may reinforce and build on the students' ability to identify themselves with other living beings, observe details, and respond to the aesthetical affordances of living nature. Such an approach may counteract a tendency towards decontextualizing and theorizing observations in science teaching.

To observe living nature with ethical attention means to recognize the dynamic and complex nature of living beings and understand the practice of observation as an emphatic engagement with living nature. To promote an emphatic engagement with the phenomena in living nature, the teacher needs to practice teaching with ethical attention towards both the phenomena in living nature and the students.

What I have argued in this chapter, by investigating the meaning of ethical attention in teaching and learning, is that exploring living nature in science education is not only a question of what kind of knowledge the students get, but how the things in living nature and the students come into being through these practices. To counteract a decontextualized science education where concepts and theories may interfere with the direct relationship between the students and the phenomena in living nature, more emphasis needs to be put on attentional practices that promote more "holistic and just relations" with living nature (Lanouette, 2022, p. 612).

14 Towards more sensible observational practices in science education in primary school

> *sensible* (adj.) - capable of sensation or feeling; also capable of being sensed or felt, perceptible to the senses, hence perceptible to the mind, easily understood; logical, reasonable. From Latin *sensibilis* perceptible by the senses, from *sensus*, past participle of *sentire*, to perceive, feel [32].

In this chapter I will elaborate on some of the issues that are brought forward in my findings in Part IV concerning practicing observation in primary school. I will explore conditions that either constrain or promote observational practices and discuss what I have called more sensible observational practices may look like in primary school. Especially, my focus is on the role of embodied and aesthetic[33] learning processes in observational practices in teaching and learning science.

Every year I do an exercise with my teacher students where they choose an insect from a collection of dried specimens and are then asked to draw it. The purpose of the exercise is to make the students observe the chosen insect carefully. What happens each time is that some of the students google their insect, and then they start to draw from online photos instead of looking at the insect they have physically present right in front of them. I get an impression that the students don't notice the difference, or even, that they think observing the photos of the insect online is somehow better than observing the physical insect. I remind them that the task is to focus on the insect in front of them, and I must occasionally ask them to put away their mobile phones. With the exercise, I want the students to practice their attention towards the insects. I intend to bring the students and the phenomena together, but the digital representations on the students' mobile phones seem to get in the way come.

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[32]From Online Etymology Dictionary: https://www.etymonline.com/word/sensible
[33]The term aesthetic has many definitions, I use the term in the phenomenological tradition and as described by Dahlin (2001): "By aesthetic I mean a point of view which cultivates a careful and exact attention to all the qualities inherent in sense experience." Thus, by aesthetic learning processes, I mean processes that enables the students to cultivate such an attention towards phenomena.

Today, digital media play a dominant role in the lives of children, and various activities on digital media fill most of their unstructured free time (Bakken, 2021, p. 30). Children spend less time than before on other activities such as playing outdoors in direct contact with nature. As shown in Chapter 2, several studies point to a missing connection between children and their local physical environment (Ballouard et al., 2011; Kahn & Thea, 2017; Miller, 2005). To describe this phenomenon, Miller (2005) uses the term extinction of experience. Experiences through digital media take away sensations that are part of any experience in physical space. In nature, this could be sensations such as the smell in a pine wood, the touch of a wet leaf, the feeling of digging in the soil, holding an earthworm, or lifting a stone to look for a woodlouse. To the children, as living bodies *in* the world (cf. Merleau-Ponty), these bodily sensations are crucial to the experience of observing living nature and recognizing the living organisms there. Studies have documented how bodily experiences contextualize science learning within the students' familiar world (Kervinen et al., 2020) and how sensory experiences and emotional involvement with living organisms are related to how children explore and create meaning (Jørgensen, 2016).

Thus, by sensible observational practices, I mean observational practices that are contextualized within the students' familiar world, and that emphasize students' sensuous, embodied experiences and emotional involvement in these practices. Such observational practices build on a combination of an attentional and intentional orientation to observation (cf. Chapter 13). The purpose of applying more sensible observational practices is to make the practices more perceptible to the students' senses, and hence more intelligible to them. My findings suggest that there are both constraints to and opportunities for more sensible observational practices in science education. In the following, I will discuss the conditions for such observational practices in primary school.

14.1 Conditions that constrain sensible observational practices

> Elise (student): "If you are looking at real plants [in nature], you get more than a picture, since then you can turn the plant around and look closely."

My findings suggest that there are missed opportunities in school when it comes to developing the students' relations with living nature and their observational skills. In addition, studies show that in science education, the students are most of the time “faced with an abstract and purely cognitive world, separated from their everyday life experiences” (Østergaard et al., 2008, p. 93), and observational practices are underestimated, or even ignored, in biology education (Eberbach & Crowley, 2009; Merritt & Bowers, 2020). Such missed opportunities might add to the loss of knowledge about living nature and to the documented widespread blindness to plants and animals (Allen, 2003; Jose et al., 2019; Knapp, 2019; Schussler & Olzak, 2008; Thomas et al., 2022).

In this section, I will discuss three conditions that seem to constrain more sensible observational practices. Such conditions are: (i) a one-sided deductive approach to teaching, (ii) the notion that only what can be measured matters in observations, and (iii) representations replace experiences with phenomena in nature. These conditions mutually influence each other, and (ii) and (iii) seem to reinforce (i). Together, these conditions for science learning induce a disconnection between the students and living nature. The students become alienated to the phenomenal world, but also to their own bodily experiences as part of learning science when representations (like concepts, theories, models) become a wedge between them and the world, instead of reinforcing connection and meaning (Figure 15).

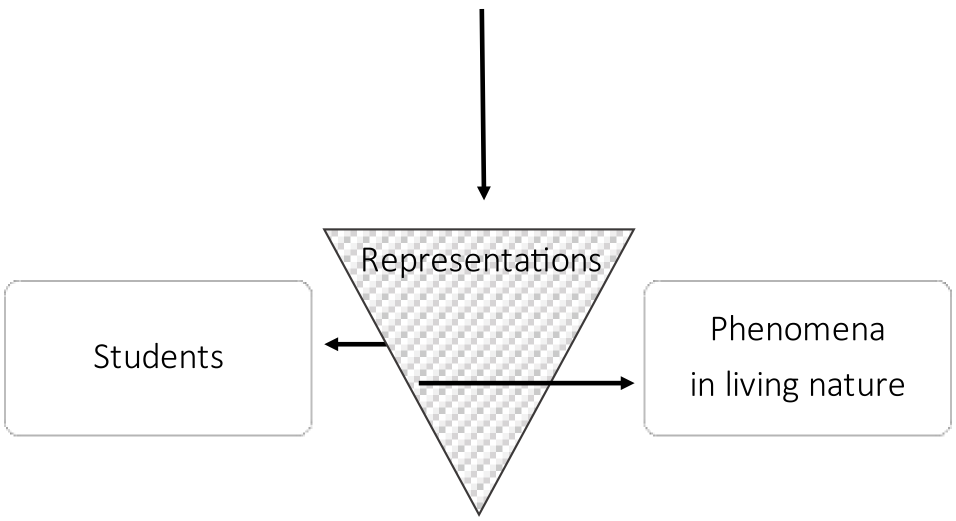

Figure 15: In science teaching representations may become a wedge between the students and phenomena in living nature.

14.1.1 A one-sided deductive approach to teaching

One of the issues brought forward in the interview with students and teachers in this project, is what it means to practice the skill of observation. The teachers and students' experiences demonstrate that practicing observation to recognize the phenomena in living nature is complex. This finding is supported by studies showing that recognizing, describing, and classifying species, is a complex, and yet an underestimated practice in education (Buck et al., 2019; Eberbach & Crowley, 2009; Merritt & Bowers, 2020). However, as discussed in Chapter 12, the teachers and students describe the process in almost opposite terms [34]. The students describe it as an inductive process, for which they need time and occasions to practice observation of the phenomena *in* nature. The teachers, on the other hand, to a larger extent describe the process as a deductive approach where the students need knowledge beforehand in order to know what to look for, which implies a process leading from general ideas to specific (predefined) conclusions. Such a deductive approach builds on an intentional orientation to observation where scientific representations such as generalized concepts, theories, and models come first and students only observe to check if the phenomena fit with these representations.

Knowledge in science is often understood as various concepts, theories, and models, which all are different forms of representations of the phenomena in nature. Multiple representation as pictures, symbols, and models are evident parts of both science per se, and science teaching and learning (e.g. Evagorou et al., 2015; Waldrip & Prain, 2012; Wu & Puntambekar, 2012). To represent something means in this context "to symbolize, serve as a sign or symbol of something else, something abstract."[35] In science, concepts, theories, formulas, and models, are representations of the phenomena in the world that seek to generalize, classify, and/or explain those phenomena. In science education, representations are also often visual representations of more abstract concepts (Cook, 2006) and thus, representations of other representations. Much research has been done in science education to investigate how representations can be

[34] As described by the teachers in Theme 2: "You have to know what to look for, so you don't just look for anything that doesn't matter" (section 12.1.2), and by the students in Theme 6: "You should always look several times to catch all the details" (section 12.2.2).
[35] represent (v.) -"show, display, express; bring to mind by description," also "to symbolize, serve as a sign or symbol of (something else, something abstract). From Online Etymology Dictionary: https://www.etymonline.com/word/represent#etymonline_v_12849

introduced and used in the science classroom to support learners' cognitive structures and processes, ranging from interpreting representations to constructing their own (e.g. Chang, 2022; Cook, 2006; Evagorou et al., 2015; Gilbert, 2004; Prain & Tytler, 2012; Waldrip & Prain, 2012; Wu & Puntambekar, 2012; Yeo & Nielsen, 2020). However, a one-sided emphasis on deductive approaches and representations in science education seems to lead to a neglect of sensory experiences with the phenomena in the world and an almost exclusive focus on conceptual cognition (Dahlin, 2001; Roth, 2015; Østergaard, 2015).

The teachers' understanding of what it means to practice the skill of observation seems to be influenced by the implicit focus on conceptual cognition and representations in science education that mainly seeks to explain and classify the phenomena, rather than primarily experiencing them. The students, on the other hand, emphasize the role of attention in observational practices, and they demonstrate a fine-tuned ability to use their senses in these practices. According to Sebastian, "you should always look several times to catch all the details" and when "you look once more, you see more", and Elise says that "if you are looking at real plants [in nature], you get more than a picture, since then you can turn the plant around and look closely". This finding suggests that an attentional orientation to observation is closer to the students' life experiences with the phenomena in living nature, than an intentional orientation to observation. The students can practice their observational skills only by engaging in observational practices, and science is only the "second order expression" of these experience (Merleau-Ponty, 2012).

Thus, by just receiving concepts, theories, and models, from the teachers, without time to first make their own experiences with the phenomena *in* nature, the students do not get a chance to make the scientific knowledge into their own and contextualize the science learning within their familiar world. As a result, the representations may become a wedge between the students and the phenomena, and the students are disconnected from both the phenomena in nature and the scientific process itself.

The teachers in this study seem to lack a firm basis, or a sense of rooting, in observational practices themselves and they express uncertainty about their role as teachers in such practices[36]. Their lack of confidence may be due to the more general underestimation of observational practices in education (Eberbach & Crowley, 2009; Merritt & Bowers, 2020) and their own lack of knowledge about the phenomena in living nature (e.g. Buck et al., 2019; Yli-Panula & Matikainen, 2014). To me, the teachers also seem somehow alienated to the task of teaching observational practices because of what they think matter in these practices.

14.1.2 Only what can be measured matters in observation.

The question of what matters in observational practices is brought to the foreground by one of the teachers in the previously discussed statement: “You have to know what to look for, so you don’t’ just look for anything that doesn’t matter”. The question of what matters in observational practices in science education, is basically a question of what the purpose of science education is, and of curriculum.

Internationally, performance in science education is often linked to measurable outcomes, and large-scale international assessments tools have a strong influence on science education policy in different countries (Sjøberg & Jenkins, 2022; Volante & Klinger, 2022). According to Clark (2022), “in a measurement culture what is measured matters and what is measured acquires increasing visibility” (p. 137) However, the students’ competencies may be limited by the measures that are used (Volante, 2018; Volante & Klinger, 2022). If the answer to the question of what matters in observational practices is ‘what is measured matters’, then all the things that cannot be measured do not matter, such as aesthetical experiences and emotional involvement. My findings suggest that what comes to matter in an observational practice in school, depends on the phenomena the students are exploring, the question they are asking, who poses the question to begin with, and the teachers’ orientation to the observation. As my four previously described modes of observation demonstrate, applying different criteria to the observation of phenomena in living nature brings out the phenomena in various ways. Different modes of observation complement each other and may invite to a

[36] As referred discussed in section 12.3.3, findings show that the teachers express a somewhat contradictory attitude when I ask them about their role as teachers in practicing observation with their students after the implementation of the project in school. One of the teachers says, “you want the students to see the same things as you do”, but he also finds it important that the students are “asking their own questions and finding their own answers”.

discussion about what matters in an observation (as discussed in Chapter 13). Colucci-Gray (2021) argues for a science curriculum that matters and that brings together knowledge and action in science education. Relevant to teaching and learning observational practices in science, she argues, by reference to Dewey (1929), that knowing is a "habit of perception":

> However, the question of training habits of perception is not simply concerned with acquiring the specialized ways of handling equipment, being able to tell an air bubble from an organelle when seeing a cell under a microscope or making science fun and attractive to increase its appeal. Rather, it is through questioning the ways in which particular sense-experiences are elicited or filtered out, legitimized or denied. It requires perceptual attention, to become aware of how our science and technological artefacts can bound and/or extend human perceptions and actions, and what consequences this can have for communities of beings who may be far away from us (Colucci-Gray, 2021, p. 25).

This means that to participate in a discussion of how different observational practices may 'bound and/or extend human perceptions' could be the most important part of practicing observation in science education, both to gain knowledge about the living phenomena in nature and to practice the skill of observation. If, for instance, only 'what is measured matters' in observational practices, the important educational question about what matters is itself taken out of the hands of both the teachers and the students. The students miss the opportunity to discuss and make the criteria in observational practices meaningful and significant to themselves, and as one of the teachers advocates for: "If you are going to observe something then it is okay to agree in advance what to look for, and then it is important (…) that the students gain ownership to it, that they have helped decide what to look for" (Thomas, section 12.1.2). Reducing observational practices to measurable outcomes could lead to the loss of important dimensions of both education and phenomena in nature.

Thus, teaching observational practices in primary school if only what can be measured matters, limits the practices by the measures that are used. Observational practices may lose important dimensions and the phenomenon under investigation is in danger of becoming less rich.

14.1.3 Representations replace experiences with phenomena

I would like to return to the following statements by one of the students: “If you are looking at real plants [in nature], you get more than a picture, since then you can turn the plant around and look closely” (Elise, section 12.2.2). The student describes the difference between observing a phenomenon in nature, and a representation in terms of a picture of the same phenomenon. A classroom seldom offers more than representations, such as pictures, texts, films, models, and abstractions, of the phenomena in living nature. With only representations present in the classroom, the students do not get a chance to position themselves according to the phenomena by using their body and senses in a physical space.

Studies indicate that there is a disconnection between children and their local physical environment (Kahn & Thea, 2017; Merritt & Bowers, 2020), and students seem to have more knowledge about virtual species (unseen, exotic) than of their local flora and fauna (Ballouard et al., 2011; Pergams & Zaradic, 2006). These studies show that the students’ experiences with the phenomena in living nature are often virtual, rather than physical. Sense experiences that are part of any physical experiences *in* nature become reduced to what the students can experience through these virtual representations. For this reason, the students will lose many of the dimension that appeal to their body and senses. However, in some cases, digital apps may bring attention to the phenomena in living nature by identifying species (e.g., iNATURE, Artsorakelet). Such tools are reported to be successful in education and citizen science project (Chozas et al., 2023). Still, apps, or any type of technology that extends our capabilities in one way or another, can be understood as “an extension or self-amputation of our physical bodies” (McLuhan, 1964, p. 50). Whether digital apps that identify plants and animals in nature extend or amputate the students’ own ability to pay attention and practice the skill of observation should be explored further.

Thus, a science teaching that mainly focuses on representations in the classroom rather than the phenomena in living nature misses opportunities to make a connection between the students and the plants and animals in their local, physical environment. As a result, science learning seems to have a loss of sense experiences that may lead to a lack of rooting (cf. Roth, 2015; Østergaard, 2015).

14.2 Conditions that promote more sensible observational practices

> Peter (student): "It [the insect] has such small hairs, then you sketch very small hairs. If it has something different from another one (…), then you observe it very well. If you see the difference between two similar species that [still] are different in some ways."

My findings suggest that there is potential for more sensible observational practice in science education that can both bring the phenomena in living nature into existence for the students and make the phenomena richer to them. In science education, there is a need to bridge the gap between embodied experiences and the concepts that belong to the field of science (Østergaard, 2015; Østergaard et al., 2007). For the science teacher this means to induce a double opening; one that opens the phenomena to the students and opens the students to the phenomena, and where the scientific representations develop genetically[37] (Wagenschein, 2015). Ingold (2018) describes "a minor science" that is an undercurrent to, and precondition for, "the major science":

> To take the measure of things, in minor science, is not to plot a series of points and connect them up with a higher order of relation. One goes not from facts 'on the ground' to theories, by in-duction, nor conversely from theories to facts by a reverse process of de-duction, but rather along the sensible path of continuous variation, that is by ex-duction. One is led out along the way (p. 41).

In Figure 16, I have described what I think of as sensible observational practices in science education. This model is a development of Figure 15 and illustrates another relationship between the students, the phenomena in living nature, and the (scientific) representations. The more sensible observational practices are illustrated as two movements: (1) the phenomena in living nature and the students are brought together and respond to each other, and (2), representations in form of concepts, theories and models develop genetically from the students'

[37] As described in chapter 2: The genetic refers to *genesis* of knowledge in the students, as coming into being of knowledge, and as the child coming into being with the knowledge. Genetic is one of three didactical principles and to make a genesis of knowledge possible, the teacher must apply the socratic principle of dialogue, and the exemplary principle to select topics to dwell on (Wagenschein, 2015).

own experiences with the phenomena and induce an opening to new experiences. In both (1) and (2) the role of the teacher is to support and facilitate these processes by being in dialogue with the students and pointing at the phenomena in nature that 'might be good, important, or worthwhile to pay attention to' (Biesta, 2022a). The observational practices become contextualized within the students' familiar world and emphasize the students' sense experiences and emotional involvement in these practices (Kervinen et al., 2020; Lanouette, 2022). As argued in Chapter 13, it is not only a question of what kind of knowledge the students get, but how the things in living nature and the students come into being through these practices.

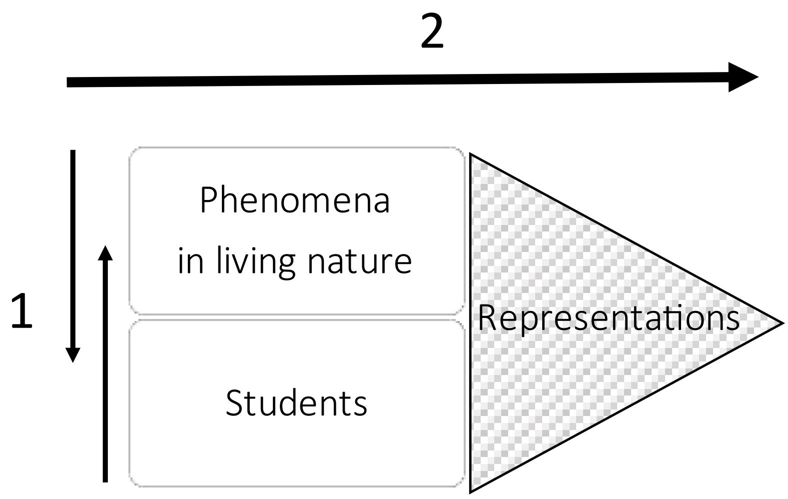

Figure 16: The two movements in sensible observational practices: (1) phenomena in living nature and the students are brought together, and (2) representations in form of concepts, theories and models develop genetically and point to new experiences.

In the following, I will elaborate on three conditions for promoting more sensible observational practices in primary school: (i) noticing more, (ii) promoting embodied modes of experiences and rooting, and (iii) contextualizing science practices.

14.2.1 Noticing more

To notice more means to counteract the overall blindness and lack of attention to the diversity of living beings in nature (e.g. Jose et al., 2019; Krosnick et al., 2018; Thomas et al., 2022). The question is how to enable the students to notice things like 'different types of grass and the other plants in between', and to see 'mushrooms and insects', as Tom describes in this quote:

> I don't think people look at the grass, they only see grass there, but if we look there are different types of grass, there are also other plants in between. You see mushrooms and insects. You have quite a large biodiversity within a fairly small area if you just look. But I think people don't observe nature, they just walk past it.

To notice more may entail looking more carefully into details like "very small hairs", to notice the nuances of differences between what seem to be similar to begin with, or: "see the difference between two similar species that [still] are different in some ways" (Peter, section 12.2.2). To notice more may also entail discovering the richness of qualities with any living organism, and the complex and dynamic contexts they are part of. To see more means to discover how living organisms are interwoven with each other (as in ecology), and part of a long history (as in evolution).

Noticing the difference

Peter's quote about seeing the difference between species brings us back to the species problem and the discussion of the species concept (e.g., Chambers, 2012; Reydon & Kunz, 2019). In the quote, Peter says that details that make it possible to distinguish between species may be more important to notice than other details.

My findings show a promising potential in the students' ability to notice details when they study and describe living organisms. In addition, both the student Sebastian, and the teacher Lisa, explicitly express that if you return to a phenomenon in living nature and look several times, you see more. The variety and diversity of living organisms seem to reveal themselves. Regarding how variation in nature reveals itself if, Darwin (1859) wrote that more varieties and species are found in those plants and animals that especially attract our attention:

> I have been struck with the fact, that if any animal or plant in a state of nature be highly useful to man, or from any cause closely attract his attention, varieties of it will almost universally be found recorded. These varieties, moreover, will be often ranked by some authors as species (p. 50).

Knowing and recognizing which details distinguish species from one another is both a practical task and a conceptual question in biology (Reydon, 2013). Species are often referred to as real entities that exist in nature, however, species are not entities that can be observed directly. In the interviews in this study, all the teachers struggle to describe what a species is, in line with most biologist. Although species is one of the most fundamental concepts in biology (Hey, 2006; Mayr, 1996), defining species as discrete entities has proved to be very difficult (Agapow et al., 2004; Reydon & Kunz, 2019). To answer the question of what species are with one reply or concept, may not even be productive (Hey, 2001; Hey, 2006). Species is a theoretical term (Reydon & Kunz, 2019), and in teaching and learning about species, students need to build a link between the species concept and the practical and complex task of identifying species (Buck et al., 2019).

In primary school, it may be more important to give the students opportunities to practice tasks of observation than focusing on the definition of species or the species concept per se. Bardy-Durchhalter et al. (2013) demonstrate how students struggled with the practical task of identifying species of deep-sea snails, although they had study material with photos of the different species. The biologist involved assumed that the students could recognize the species immediately by looking at the photos. In the study they concluded that for the students to recognize species, teaching needs to "include evolutionary perspectives like homologies and analogies", "point to the inherent natural variability of all biological organisms", and "point out diagnostic characters as tools" (p. 59-60). With a phenomenological approach and building on the genetic principle (cf. Wagenschein), I will argue that students first need to gain experience with observing many different plants and animals and practice their skill of observation to discover the 'natural variability of all biological organisms' in nature themselves. For students in primary school, Aristotle's comparative mode of observation is one way to discover the variety of living organisms without first introducing a species concept or the theory of evolution. Using this comparative mode of observation in science class, the students may develop, for instance, questions and ideas about a species concept(s) from their own experiences. The approach connects the students with the phenomena in living nature and opens a path to new discoveries if the students get a chance to watch, listen, and respond to what they observe. For instance, this can be achieved by comparing different insects to find similarities and differences between their legs, wings, or mouthparts, and wondering about the form and function of the different parts. In such a comparative mode of observation, there is a potential for the students to notice more and start to discover the wide variety of living organisms.

Noticing the complex and dynamic context

My findings further suggest that for the students to observe and describe what they see either orally, in writing, by drawing, or by making a diorama, will bring out a larger variety of qualities of the phenomena. There is a potential for noticing more when the students respond to the phenomena by using their senses, engaging, asking, drawing, and creating. When the students, inspired by Merian's holistic and aesthetical mode of observation, studied butterflies, and made models of the life cycle of different species, they brought out a great diversity of qualities of the butterflies. These models exhibited the butterflies' aesthetic qualities, like their colorfulness and beauty, in addition to other qualities like the butterflies' changing and entangled form of being. The students developed their personal representations from their own observations of and experiences with butterflies. With this approach, the teachers were able to support the process of bringing the phenomena in living nature and the students together, and models of the butterflies' life cycle could develop genetically from the students' own experiences (cf. Figure 16).

To notice more, the students need to cultivate their attention towards the phenomena in living nature in ways that makes the phenomena richer. According to Dahlin (2001),

> we can keep the same objective as science, and still put more emphasis on the aesthetic dimension of knowledge formation. By aesthetic I mean a point of view which cultivates a careful and exact attention to all the qualities inherent in sense experience. The objective of such an approach to natural phenomena would be not merely to appreciate their beauty, but also to understand them (p. 454).

Ecology has its roots in direct observation and careful descriptions of the phenomena in living nature (Merritt & Bowers, 2020; Sagarin & Pauchard, 2010). Studies report that knowledge and skills gained by learning to recognize plants can also promote further exploration in ecology and "foster an intimacy between a student and nature" (Ebert-May & Holt, 2014). For students in primary school, cultivating "a careful and exact attention" (cf. Dahlin, 2001, p. 454) towards living beings in nature is also a way to discover the complex and dynamic context they themselves are part of.

14.2.2 Promoting embodied modes of experience and rooting

Embodied modes of experience go beyond the conceptual and cognitive dimensions of learning science (Kervinen et al., 2020; Lanouette, 2022). I understand the embodied modes of experience in observational practices as the aesthetic, emotional, and various physical experiences that are part of the students' lived experience with the living phenomena. My findings show that the phenomena in living nature have aesthetic qualities that appeal to the students' senses and responses. For instance, according to the students the phenomena in living nature are colorful, they can be touched, smelled, and tasted, they make sounds, they move and grow, and nature can be something they can go into. I suggest calling these aesthetical qualities of living nature *aesthetic affordances*.

Aesthetic affordances of living nature

The theory of affordances is described by Gibson (2014) in the book *The Ecological Approach to Visual Perception*. Originally, the term affordances refers to what an environment offers, provides, or furnishes, an animal (p. 119). According to this theory, there is a complementarity between the one who perceives and the environment, and the environment of an organism is what the organism perceives (p. 11). Gibson claims that the world of ecological reality (as opposed to the world of physical reality) consists of meaningful things and that "their meanings can be discovered" (p. 28). Meanings do not have to be imposed on what we perceive as things in nature. To perceive things is to perceive what they afford, and the radical implication is that "the "values" and "meanings" of things in the environment can be directly perceived" (p. 119). While physical properties in an environment are general and abstracted descriptions, the affordances of an environment are always relative to the one who perceives the environment. An environment offers and affords various qualities to different living beings according to their way of living.

My findings show that there is a complementarity between the students' embodied sense experiences and an environment of living nature with various and manifold aesthetic qualities. As living beings, the students are part of an ecological reality (cf. Gibson) that (already) consists of meaningful things. When the students perceive the phenomena in living nature as colorful, or something that can be touched, smelled, and tasted, moves, or grows, they perceive what these phenomena afford to them. Following Gibson's theory of affordances and his idea about an ecological reality, these aesthetical qualities also give meanings to the phenomena in living nature for the students.

For students in primary school, the aesthetic affordances with living nature imply that living nature affords aesthetic experiences that may promote responses in the students. My findings suggest that living plants and animals appeal to the students' senses and their curiosity. Responding to the living beings in nature calls for a positioning of the students' bodies (embodied learning) to let the phenomena show themselves and possibly promote empathetic emotions of identification in the students. The students feel invited and like to be *in* nature, or as one of the students says: "Yes, I really like sitting *in* nature" (Mia, section 12.2.1). In Figure 17, I have summarized what I see as the aesthetic affordances with the phenomena in living nature, and the students' aesthetic experiences and responses to these affordances. In relation to Figure 16, the first movement of bringing the phenomena in living nature and students together, may both support, and be supported by, giving the students opportunity to experience the aesthetic affordances in living nature.

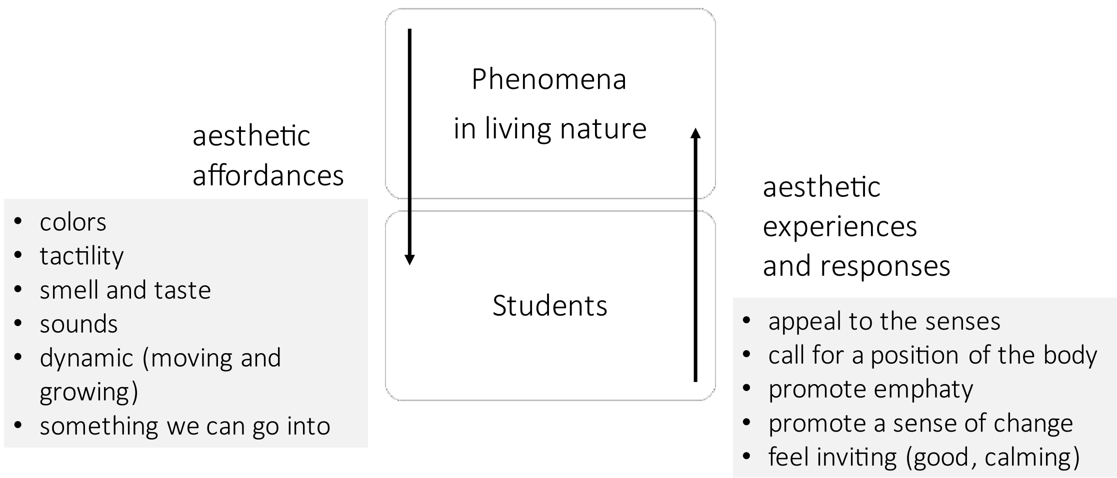

Figure 17: The aesthetic affordances with the phenomena in living nature, and the students' aesthetic experiences and responses to these affordances.

An education of attention

A prerequisite for the students to experience the aesthetical affordances in nature is that the students educate their attentiveness. Similar to the term affordances, Østergaard (2023) uses the German term *Aufforderungscharakte*r to describe nature's invitational character, and underscores the importance of accepting the invitation and being able to pay attention:

> Nature's *Aufforderungscharakter*, its invitational character, is experienced only in a state of openness when we accept the invitation. Whereas attentive listening is a competence to experience nature as manifold soundscapes, inattentive hearing might create the impression that nature is silent or, at the most, a *muzak* soundscape for human activity (p. 5).

Being attentive is a competence to experience the manifold aesthetical qualities nature has to offer, and it is a competence students need to practice. According to Ingold (2018), by reference to Gibson's work, "we become familiar with this environment not by looking *at* it (…), but by moving around *in* it", and a growing familiarity "comes from a gradual fine-tuning or sensitization of perceptual skills that renders perceivers ever more attentive to the nuances of the environment" (p. 31; italics in original). In line with the students and teachers' experiences, referred to above, that you see new things if you return to the same phenomena several times, there is always more to be discovered in the real world, as opposed to "the world of its representations" (p. 31). To practice observation means to attune the perceptual system so that it resonates with the environment.

> The more practiced we become in walking the paths of observation, according to Gibson, the better able we are to notice and respond fluently to environmental variations and to the parametric invariants that underwrite them. That is to say, we undergo what he called *an education of attention* (Ingold, 2018, p. 31; my italics).

One of the students demonstrates how he has trained his attentiveness and attuned his perceptual system when he says:

> And then I have discovered a lot of new things about butterflies, what they look like and so on. When I see a butterfly, I kind of think (..) it's yellow and red, but then I kind of saw that they are not just that (Sebastian, section 12.2.1).

According to Merleau-Ponty's (2012) body-phenomenology, sensations are "enveloped with a living significance" and sensing is understood as a coexistence with the world (p. 216- 217*)*. Sensing as a coexistence with the world seems to be demonstrated by the correspondence between the 'affordances' with the phenomena in living nature and the students' embodied experiences with the same phenomena. For the students to attune their perceptual system so that it resonates with the environment and to undergo *an education of attention*, there is potential to promote a (deep) sense of rooting in the students.

Rooting in science education

To promote rooting in science education implies to counteract the tendency of alienation from nature and the physical environment, and rather build on the students' familiarity with the world (Roth, 2015; Østergaard, 2015). Our "everyday common sense constitutes the ground in which all of our scientific understanding is rooted" (Roth, 2015, p. 470). Østergaard (2015) describe two conditions for rooting in science education: "restoring the value of aesthetic experience", and "allowing time for open inquiry" (p. 522). To build on the correspondence between the 'affordances' of the phenomena in living nature and the students' embodied experiences with the same phenomena is one way to restore the value of aesthetic experiences in observational practices.

The importance of children interacting with nature is also described in a study by Kahn and Thea (2017). According to the authors, the power of interaction with nature "comes from living these forms of interaction in endlessly diverse ways, always alive, never the same twice" (p. 20). In the study, they describe basic interactions with nature, like falling on the ground, or digging in the soil, but also an interaction of *calling the birds*. The children in an outdoor kindergarten are taught how to imitate some of the local bird calls, and the authors describe a situation where a girl spends several minutes first being quiet in a secluded area, and then starts calling the birds. The girl's *calling the bird*' is described in the article as an embodiment of a relational form of interaction with nature between humans and birds (that has a long history), where they answer to each another. In other words, there is a correspondence between the affordance of birdsong in the environment and the girl calling for a bird. The phenomenon of birdsong in the woods calls for the girl to position herself to let the phenomenon show more, and at the same time the girl actively calls for the bird by imitating the bird. In the act of *calling the birds*, the girl pays attention to the bird and practices how to attune her perceptual body so that it resonates with the environment. By returning to the phenomenon several times, she may fine-tune her perceptual skills to be ever more attentive to the nuances of birdsong.

Thus, in the embodied modes of experiences that go beyond the conceptual and cognitive dimensions of learning science, there is a potential to undergo an *education of attention* (cf. Gibson). To educate the attention implies that the students and the phenomena are brought together and correspond with each other (Figure 16), and the students are (re) introduced to an ecological reality that consists of meaningful things. Observing living nature understood as various attentional practices means to cultivate the students' aesthetic experiences and embodied responses to the phenomena in living nature.

14.2.3 Contextualizing science practices

An ongoing challenge in science education is to foster the emergence of science practices that are useful and meaningful to children and that also elevate "the heterogeneity and variability inherent in science sensemaking" (Lanouette, 2022, p. 611). When I use the expression 'contextualizing science practices' for students in primary school, I mean to make the practices personal, connected to a time and a place, instead of making them general and abstract. I will argue that contextualizing science practices can make these practices more useful and meaningful to students. Furthermore, at the same time contextualizing science practices can demonstrate various forms of questioning and knowing in science to develop the students understanding of scientific practices. In the following, I will elaborate on two ways to contextualize science practices in science education: (a) to make practicing science a case-by-case investigation, and (b) to tell the students personal stories about historical explorers.

To make practicing science a case-by-case investigation

My study shows that the students in primary school were able to recognize and make meaningful some essential aspects of observational practices in science through the four teaching cases from the history of science, such as observing carefully, taking notes, and making systems. My findings also show that the teachers' answers to what scientific observational practices are, point in different directions and demonstrate some of the complexity in describing scientific practices. Another significant finding in this context is that the teachers find it hard to distinguish between describing and explaining, which may be very important in scientific practices.

I will argue that science practices can be contextualized by exploring the characteristics of science in “a ‘case by case’ investigation” (Irzik & Nola, 2014, p. 1011), instead of trying to generalize the scientific processes and define the nature of science (NOS). By a case-by-case investigation I mean exploring the concrete scientific practices in specific historical (or contemporary) cases. As discussed in Chapter 2, difficulties with defining NOS in science education has led to a consensus-view that has been criticized for not doing justice to the richness of science, and for giving an impression of science as fixed and timeless (Irzik & Nola, 2010, 2014). The family resemblance approach (FRA-model) offers an alternative way to learning about science practices. With this approach, science is structured in eight categories which all consist of an open-ended set of items, and descriptions of science practices form a network of similar and different items and characteristics within these categories. The four categories that belong to ‘Science as a cognitive-epistemic system’ in the FRA-model, and that I find most relevant in to my project, are: 1. Processes of inquiry, 2. Aims and values, 3. Methods and methodological rules, and 4. Scientific knowledge (Irzik & Nola, 2014, p. 1009). Furthermore, these four categories constitutes the inner circle, or the core, in the FRA-wheel by Dagher and Erduran (2016, p. 155)

To see how the FRA-model may be useful for teaching and learning scientific practices in primary school, I have explored how the four categories that belong to ‘Science as a cognitive-epistemic system’ apply to the four historical teaching cases in my project. I have summarized my findings in Table 15. I will elaborate on some of the aspect in this case-by-case investigation that can make science practices useful and meaningful to students in primary school. In addition, I will show how such an approach may elevate “the heterogeneity and variability inherent in science sensemaking” (cf. Lanouette, 2022, p. 611).

Table 15: A case-by-case investigation of the four categories belonging to 'Science as a cognitive-epistemic system' in the FRA-model (Irzik & Nola, 2010)

Case	Processes of inquiry	Aims and values	Methods and methodological rules	Scientific knowledge
I	Comparative observation	Describe 'eidos' of a unique kind of being. All living beings may reveal something important about nature	Comparison of analogous, generic, and specific characteristics (both form and function)	Comparative descriptions of the form and function of parts of animals
II	Aesthetic and holistic observation	Describe living beings according to nature	Accurate descriptions	Visual and aesthetical descriptions of butterflies and their life cycles
III	Analytical and systematic observation	Make a system of classification	Quantitative analysis	A system of classification of plants and animals
IV	Synthetical and explanatory observation to construct a theory.	Make explanation and prediction	Causal explanations	A theory of evolution of all living organisms

In all four cases, the main process of inquiry is observation, however, these four cases demonstrate different modes of observational inquiry. *In case I*, the process of inquiry is comparative observation, and the aim is to describe an organism's unique way of being. There is an underlying value that all living beings may reveal something important about nature. The methodological rules to follow are meant to make comparison easier, not having to repeat the same characteristics several times. For instance, all animals have a mouth in one form or another, this is an analogous character. When comparing different animals, the interesting part is observing what sort of mouth each animal has and compare similarities and differences between them. For students in primary school, comparing insects, to investigate how they differ and how they are similar, can be a good exercise. The students can compare the form and function of different parts like legs and wings in the different insects. From such an observation, the students arrive at scientific knowledge in terms of comparative descriptions of the form and functions of different parts of insect. This can help them group the insects and gradually make classification of insects more comprehensible. To discuss what is unique about a certain organism, and what the characteristics are that distinguish one from the other, the students are invited to a dialogue about the criteria for a comparison and what a species is (Nyléhn & Ødegaard, 2018).

In case II, the process of inquiry is an aesthetic and holistic observation, and the aim is to describe living beings according to their nature. The underlying value is to describe the living beings as we experience them, including both aesthetical qualities, dynamics, and interactions with other living organisms. The methodological rule to follow is accurate descriptions, which means that the skill of describing is essential, and must be practiced in this mode of observation. For students in primary school, describing the life cycles of butterflies by making models that include both details and context, can be a good exercise. From such an observation, the students arrive at scientific knowledge in terms of visual and aesthetical descriptions of butterflies and their life cycles. The task invites to a dialogue with the students about the criteria for a description of the dynamic, entangled, and colorful, dimensions of living organisms. The students also practice science by making their own visual models of the lifecycle of specific species of butterflies. About the implementation of the case of Merian with the students in fifth grade, one of the teachers says that the students were "able to transform it [observing butterflies and creating models] into their own" (Lisa, section 12.3.2). This implies that this way of describing butterflies was intelligible to the students. The students were able to build the practice on their familiarity with the phenomenon and the materials that were used. Here, they demonstrated a careful and exact attention to details.

In case III, the process of inquiry is an analytical and systematic observation, and the aim is to make a system of classification. The underlying value is to use criteria for classification that can be counted or measured and that everyone can agree on. The methodological rule to follow is to perform quantitative analysis and examine elements in the structure of a living organism, for instance, the parts of a flower. A prerequisite for such quantitative analysis is to know the names of those elements and to be able to recognize them, in addition to having an idea of a classification system beforehand. Students in primary school need to know what to look for when classifying plants in families or genera by analyzing the structure of a flower. Such an exercise entails that the students learn about of the structure of a flower and practice recognizing different flower parts by looking at many different flowers before they can start to classify the plants by such criteria. From such an observation, the students can gradually arrive at scientific knowledge in terms of a system of classification. The implementation of the case of Linné in fifth grade in primary school shows that students recognize and make meaningful the practice of making systems. When the students describe what Linné did as a scientist, they emphasize that he sorted and organized the plants in shelves, gave them names, and that having a system made it easier to locate the plants. The students made the practice meaningful by comparing Linné's system with their own systems of sorting their football-cards or color-pencils, and they recognized and put into words what it means to make a system. However, when I asked the students to sort some plants that I had brought with me to the interviews, all of the students sorted the plants by flower color, and not by any quantitative criteria. This indicate that sorting plants by the number of petals or stamens is not intuitive to the students in primary school. However, students can still practice science by making systems and trying to classify plants themselves, and through this be invited to discuss the criteria of classification.

In case IV, the process of inquiry is synthetical and explanatory observation to construct a theory. Here, the aim is to make explanations and predictions of the observation of living organisms. The underlying value is that there is a theory that can explain all these observations. The methodological rule to follow is to synthesize and generalize observations to find causal explanations and make a general theory, and then check if the theory fits with other observations. A prerequisite for making causal explanation of the living phenomena in nature is to have an idea of a theory beforehand. For students in primary school, we cannot expect that they arrive at an abstract theory by making observations. However, by engaging in comparing insects (cf. Aristotle), describing butterflies (cf. Merain), making system of plants (cf. Linné), they will probably start to ask why and look for explanations. Students in primary school can for instance be given the task of observing different beetle legs, or bird beaks. To facilitate the students' search for explanation, the teacher can ask them to reflect on why different beetles have different legs, and further, what may be the story behind each animal's fine-tuned adaptions to their environment. From such an observation, and supported by the case of Wallace and Darwin, the students may gradually arrive at scientific knowledge in terms of a theory of evolution. With this task, the students are invited to discuss what explanations and theories are, and how to make explanations themselves. They are enabled to practice how to make abstractions out of their own experiences (cf. Wagenschein). The implementation of case IV in fifth grade showed that it was harder for the students to describe the practice of Wallace and Darwin, than the practices represented by the three other cases. The students emphasized that Wallace and Darwin traveled to other parts of the world to get another view of what animals were like. However, none of the students mentioned that Wallace and Darwin made explanations or constructed a theory on the basis of these observations, although the topic of making explanations was emphasized in the booklet for case IV.

Altogether, these modes of observation show that being in dialogue about what matters in an observation is a way to make scientific practices useful and meaningful to students in primary school. At the same time, different modes of observation demonstrate various ways of questioning and knowing in science. Table 16 shows how the FRA-model to NOS may be used as a dynamic tool for both teachers and students to investigate and compare cases of scientific practices, and to find how the science categories contain similar or different items from case to case. The exploration could be expanded by comparing these cases, or other selected cases, regarding the four categories belonging to "Science as a social system": 5) Professional activities, 6) Scientific ethos, 7) Social certification and dissemination of scientific knowledge, and 8) Social values of science" (Irzik & Nola, 2014, p. 1009). Through a case-by-case investigation, a more nuanced picture of scientific practices may emerge of science being both ongoing and historical, rather than fixed and timeless. In addition, this approach to knowing science also takes into account what might be specific to a scientific discipline, as biology in this case (Morante & Rossi, 2016).

Telling stories about historical scientific pioneers

After the implementation of the teaching cases in Phase 3, the teachers Victoria and Tom especially emphasize the story about Merian as appealing to the students. They report that the students remembered a lot of details about her and that the way in which the story was told enabled them to imagine how her life was. It seemed to be easy for the students to identify themselves with the story of Merian, as well as her approach to observing the butterflies. When the students describe what Merian did as a scientist, they emphasize that she collected specimens of butterflies and looked after them, that she observed a lot, looked closely, and every day wrote down what she saw. In this case, the story about Merian probably served to humanize science and make the observational practices meaningful to the students (Hadzigeorgiou, 2016; Tala & Vesterinen, 2015).

Science practice can be contextualized by the teacher telling the students stories about historical (or contemporary) scientists and what they did to answer a specific question or a problem. In science education, there has been a growing emphasize on the advantages of using stories and narrative thinking as means to understand science (e.g. Dahlstrom, 2021; Hadzigeorgiou, 2016; Hadzigeorgiou & Schulz, 2019; Martin & Brouwer, 1991). Telling stories that are context-specific may help the students to create meaning out of what would otherwise probably have been abstracted and generalized concepts and theories (Martin & Brouwer, 1991). Storytelling, either as historical or contemporary cases, that portrays scientists and their practices, may also serve to humanize science and illustrate connections between science and society (Matthews, 2014; Tala & Vesterinen, 2015). However, science and storytelling might represent contrasting ways of understanding reality (cf. Bruner). Furthermore, storytelling may contribute to scientific misinformation, as well as engage and help people understand science (Dahlstrom, 2021). How such stories should be designed for teaching is not given, and according to Heering (2010), the central question is: “What kinds of stories are useful for what kind of science teaching?” (p. 323). In other words, the objective in science education is to distinguish which stories are adequate or not adequate (Allchin, 2003; Heering, 2010).

I will argue that the major objective in science education is to tell stories that foster science practices that are useful and meaningful to students, by emphasizing questions, the methods used to resolve the question, and the answers to the question. In Chapter 11, I have described how I designed the four historical cases I used in this study. To illustrate the processes and contexts of knowledge generation, the cases describe as far as possible the very concrete investigations that the central actors in each case took part in, like where they were, what kind of specimens they studied and what kind of equipment they used. For instance, the case of Linné describes among other things, his office, the look and size of the cupboard he used to store his herbarium, how he made his notes, the file index he used to store his notes, and the botanical garden he used as a kind of living textbook for his students. In the case booklet, the students were invited to imagine and make drawings of his office and all the things he stored there. The case of Merian describes, among other things, her growing up, first in a printing house, then in a painting studio, and her job to collect insects in the garden for her stepfather who painted them. The case invites the students to imagine the smells and sounds in these places.

To understand observation as ways of engaging and communicating with the world (cf. Merleau-Ponty) means that a certain mode of observation is a positioning of the body, rather than having a perspective on the world. Science teachers can only invite their students to position themselves in different modes of observation, and not telling them what they see. In teaching and learning scientific practices, telling stories about real persons, the questions they asked, and the equipment they used, may help the students to imagine how these persons practiced their exploration and then stimulate the students to try out different modes of observation themselves. In different positions, or in different modes of observation, the phenomena will be experienced differently. With the help of stories about historical (or contemporary) scientists the students may investigate interactions between questions asked, practices, personal characteristics, time, and places to gradually develop knowledge of scientific practices.

14.3 Potentials and constraints of the curriculum

The teachers' practice in the science classroom is governed by the science curriculum. In different countries, the science curriculum may have various and mixed purposes, and different arguments for teaching and learning science "have different implications for the choice of curriculum content and learning outcomes, and hence for methods of teaching and assessment" (Millar, 2014, p. 17). In the Norwegian science curriculum, the first section describes the relevance and central values of the subject and emphasizes for instance that science education "shall contribute to the pupils' sense of wonder, curiosity, inventiveness, engagement, and innovation", and give them "insight into how people's way of life and actions affect life on Earth" (UDIR, 2020, offical

English translation). The text further aligns with the democratic argument of science education (e.g., Millar, 2014) that says that an understanding of science is needed for everyone to gain informed views and be able to engage in discussions and debates in society. However, how such a purpose shapes the curriculum depend on culture and ideology (Colucci-Gray, 2021). In addition to core elements, interdisciplinary topics, and basic skills, the Norwegian science curriculum for primary school is further described by more specific competence aims after year two, four, and seven (UDIR, 2020). The notion of *aims* in the Norwegian science curriculum seems to be in line with a "rationalist ideology" and of "tasking teachers with setting objectives and measuring specific outcomes" (Colucci-Gray, 2021, p. 24).

I will argue that the Norwegian science curriculum represents both potentials and constraints for the teachers to apply more sensible observational practices in primary school. The central values in the science curriculum, as promoting a sense of wonder, curiosity, and engagement, seem to support, and be supported by, what I have called more sensible observational practices. On the other hand, the notion of competence aims, and as I will show below, the emphasis on causal explanations and conclusions in some of these aims, could potentially constrain the observational practices. With specific aims there is an expectation of specific outcomes that can be measured, and it is possible that the students' skills may be limited by the measures that are used (Volante, 2018; Volante & Klinger, 2022).

One of the competence aims after year seven relevant to this project is: "The pupil is expected to be able to explain how organisms can be divided into main groups and give examples of the special features of different organisms." Another competence aim concerning learning scientific practices is: "The pupil is expected to be able to distinguish between observations and conclusions, structure data, use cause and effect arguments, draw conclusions, assess sources of errors and present findings" (UDIR, 2020, official English translation). The focus on the student being able to *explain* "how organisms can be divided into main groups" and to "use cause and effect arguments", emphasizes explanation and seems to neglect the role of other skills like observing and describing living nature. However, what it means "to explain how organisms can be divided into main groups" can be discussed and interpreted in several ways. With a one-sided deductive approach to science teaching with a focus on cognitive processes, representations, and generalized explanations, there is a risk that the students learn to make such an explanation without being in touch with the phenomena in living nature at all. However, applying what I have called sensible observational practices, would entail that students are enabled to make explanations that are contextualized within their familiar world. For instance, letting the students practice noticing and discovering the richness of qualities of living organisms in nature and then letting them discuss criteria of classification, can make an explanation of "how organisms can be divided into main groups" meaningful. The third competence aim that is relevant to this project seems to align well with what I have described as a case-by-case investigation of scientific practices: "The pupil is expected to be able to give examples of how natural-science knowledge has developed and continues to develop" (UDIR, 2020, official English translation). The notion "to give examples of" implies contextualizing science practices as I have argued for, rather than generalizing them and explaining the nature of science. However, "to give examples of" is a rather vague formulation, and the teachers need to concretize what it means and what kind of examples to choose. Thus, depending on how the competence aims are interpreted by the teachers, they may represent both potentials and constraints for applying more sensible observational practices.

In my study, the teachers were not asked explicitly about how they perceived the role of the curriculum in this project, but the curriculum is still mentioned or referred to in the interviews on some occasions. None of the teachers expressed that they found the project to be outside of the curriculum. On the contrary, according to Victoria, the project is in line with the new curriculum[38]:

> I have mostly focused on *why*-questions [in my teaching], but I think questions starting with *what* are just as important, and there is a bit more of this in the new curriculum, focusing on *what*. Focusing on what you see, observation and descriptions (..) Yes, more focus on the process itself[qqq].

Her statement is probably a result of her understanding of the first section of the curriculum, about relevance and central values, that was published before the

[38] The interview was conducted in spring 2019, and the new curriculum was implemented in 2020. Victoria's answer applies to what was then the new and expected curriculum.

competence aims, and may also be influenced by being part of this project. She understands the processes of observation and description to have a larger focus in the new curriculum, and thus, the project to be in line with this curriculum.

A statement by Tom demonstrates how focusing on measurable outcomes in teaching may limit both the teachers' practice and the development of the students' skills. He expresses how becoming more experienced as a teacher has affected his interpretation of the competence aims:

> When I was a new as a teacher, I was more afraid to work exploratory [with the students] because it felt safe to have specific measures that the students could be tested by. It is difficult to measure how rational the students have become today, or how they have developed their critical thinking today (…), how exploratory they are. It is easier to take a test and see if they remember this (…) this fact. It is easier and perhaps safer to set up the teaching where you have something to test (…) They [the students] have learned what they are supposed to learn. But then gradually... when I've become a little more experienced, I've gained more courage to perhaps do it my way, the way I want it to be. That's how I've realized that it should be too, how they [the government/ the school-leaders] want it (…) In the exploratory way (…) It has gotten easier over time being able to do it like that.[rrr]

The statements by Victoria and Tom show how the curriculum may be interpreted by the teachers and how their perception of what matters in science teaching can change. Practicing observational skills to explore living nature is fundamental in science teaching and can be argued for by referring to the curriculum. This applies to both the curriculum's central values, the core elements, the interdisciplinary topics, the basic skills, and the competence aims. In the end, the way in which the curriculum is practiced and expressed in the classroom, is affected by how the teachers understand the purpose of science teaching and learning. Thus, there are both potentials and constraints in the curriculum to applying more sensible observational practices. However, other factors such as culture and ideology in school and the teachers' former experiences will affect how the curriculum is implemented.

14.4 Conclusions

In this chapter, I have introduced two models. The first model shows how (scientific) representations may become a wedge between the students and the phenomena in living nature under certain conditions, instead of bringing them together (Figure 15). The second model is a development of the first and illustrates more sensible observational practices as two movements (Figure 16). In the first movement (1) the phenomena in living nature and the students are brought together and respond to each other. In the second movement (2), representations in the form of concepts, theories, and models with the support of the teacher develop genetically from the students' own experiences with the phenomena and encourage an opening to new experiences. In both (1) and (2) the role of the teacher is to support and facilitate these processes.

In Table 16, I have summarized the conditions that have been discussed in this chapter and which either constrain or promote more sensible observational practices in primary school. I have described the three conditions that constrain the two movements (1) and (2) discussed above, and the three conditions that promote the two movements (1) and (2). I have also summarized *how* each of these conditions either constrains or promotes movement (1) and (2).

Table 16: An overview of conditions that either constrain or promote more sensible observational practices.

Conditions that *constrain* the movements (1) and (2)	Phenomena and students are brought together and respond to each other (1)	Scientific representations develop genetically from the students' own experiences and induce an opening to new experiences (2)
(i) a one-sided deductive approach to teaching,	Focus on cognitive processes and conceptual learning may introduce a wedge between the students and the phenomena	Alienation towards both the phenomena and the scientific processes that close, rather than open, for new experiences
(ii) the notion that only what can be measured matters in observations	Practice observation with predefined measures may limit the students' competence by the measures that are used.	Lose the important dialogue about what matters in observational practices
(iii) representations replace experiences with phenomena in nature	Practice observation based mainly on representations; the students miss opportunities to experience the physical/ living phenomena in nature	Lose important dimensions of sensing and embodied experiences that go beyond the cognitive aspects, as base for developing scientific knowledge.
Conditions that *promote* the movements (1) and (2)		
(i) practice noticing more	Practice tasks of observation in contact with the phenomena in living nature, and let the students discover the richness of qualities with an animal or plant	Let the students develop models, theories and concepts that are contextualized within their familiar world.
(ii) promoting embodied modes of experience and rooting	Cultivate the correspondence between the students' embodied experiences and the affordances of the phenomena in living nature	Let the students undergo an *education of attention* by moving around in the environment to discover ever more nuances and discover new 'things'
(iii) contextualizing science practices	Practice various observational practices with different forms of inquiry, aims, methods, and knowledge. Telling context-specific stories about how others have explored living nature	Investigate applied observational practices case-by-case to gradually develop knowledge of scientific practices. Investigate interactions between questions asked, practices, persons, time, and places in histories of scientific pioneers.

15 Methodological reflections, implications, and conclusions

In this chapter, I will reflect on how I have experienced the research process and point to some implications of my work for both teaching practices and research. I will reflect on my own modes of observation as a researcher as well as my ethical attention in the process. Further, I will discuss some topics and questions for further research. Finally, I will attempt to summarize my answer to the overall research question: *What is the nature and meaning of observing living nature in science education in primary school?* After that I return to my own lived experience of being both a PhD-student and a teacher educator and describe a project I have undertaken with my teacher students in the same period of time.

However, I will start by pointing to a possible fifth teaching case about observing living nature that might complement the four previous discussed teaching cases.

15.1 Observation from non-human points of view – a fifth teaching case?

> I want to know what it is like for a bat to be a bat. Yet if I try to imagine this, I am restricted to the resources of my own mind, and those resources are inadequate to the task. (Nagel, 1974)

When observing earthworms in a terrarium in the classroom, one of the students says: "How do they sense [perceive their environment]?" I find the question intriguing because it enables a whole new mode of observation from another point of view, and it introduce a possible fifth teaching case.

I have argued that to practice an ethical attention towards living organisms, the students need to respond to and relate to other living beings, rather than just identifying them. I have also argued for observational practices that are more sensible. By that, I mean practices that are contextualized within the students' familiar world, and that emphasize students' embodied experiences and emotional involvement in these practices. Implications for teaching in primary school are that the teachers need to consider how students can engage responsibly in observational practices that include, but also go beyond, the conceptual and cognitive dimensions of learning science. In the following, I will give a short sketch of a fifth teaching case that entails such approaches and that might complement the other four cases.

Jakob von Uexküll (1864 -1944) was a biologist concerned with how other living organisms perceive their surroundings. He argues that other organisms have species-specific and subjective ways of experiencing the world, which he calls *Umwelt* (von Uexküll, 2010). *Umwelt* is literally translated as 'surrounding world' or environment, and with the notion of *Umwelt* von Uexküll describes how a living organism actively interprets and organizes its environment. His investigations point to questions such as: What is it like to be a woodlouse or an earthworm? What is essential to earthworms and their ways of being in the world? As a mode of observation, he turns the perspective around. The observation is not about what the biologist, teacher, or students see, it is about trying to understand how other organisms observe and experience their world. Thus, the main question that von Uexküll seeks to answer is: How do non-human living beings perceive their world?

In the foreword of the book *A Foray into the Worlds of Animals and Humans*, which was first published in 1934, von Uexküll (2010) writes:

> The environments, which are as diverse as the animals themselves, offer every nature lover new lands of such richness and beauty that a stroll through them will surely be rewarding, even though they are revealed only to our mind's eye and not to our body's. We begin such a stroll on a sunny day before a flowering meadow in which insects buzz and butterflies flutter, and we make a bubble around each of the animals living in the meadow. The bubble represents each animal's environment and contains all the features accessible to the subject. As soon as we enter into one such bubble, the previous surroundings of the subject are completely reconfigured. Many qualities of the colorful meadow vanish completely, others lose their coherence with one another, and new connections are created. A new world arises in each bubble (p. 43).

In the book, von Uexküll investigates what he calls an animal's perception signs (*Merkzeichen*) to answer the question of how living beings other than humans perceive their world. Perception signs …

> …denote not primarily something about the object [which the animal is perceiving], its features, but something about the way in which the subject [the animal] organizes its *Umwelt* through selective perception of those

features, which are only relevant insofar as they are relevant for the subject (or the subject's species) (p. 36).

By seeking out an animal's perception signs and observing its behavior or activities, von Uexküll aims to make inferences about how the environment appears to the animal. In his book he uses a lot of examples and thoroughly investigates things like different animal's perception signs of time and space, how form and movement of an object may work differently as perception signs to different animals, and the meaning of a familiar path through an environment to different animals. I will exemplify by describing how he investigates the environment of the earthworm and whether there is a perception sign for form in its environment.

By reference to Darwin (1881), von Uexküll (2010) writes that "earthworms treat leaves and pine needles differently according to the form of each" (p. 82). The earthworms pull both leaves and needles into narrow tunnels in the ground, but they differentiate between how they pull either the leaf or the pair of pine-needles. They pull the leaves by the tip of the leaf, and the pair of needles from the base, and in this way both the leaf and the pine-needle easily follow into the tunnel. The question is whether the earthworm perceives the different forms of the leaves and the pine-needles and therefore handles them differently, or whether there are other perception signs that make the difference. According to von Uexküll, further experiments have shown that earthworms treat the leaves differently not according to their form, but to their taste. Taste is the perception sign that makes it possible for the earthworm to distinguish between the stem and the tip of the leaves, or the pair of pine-needles, and pull them into their tunnels the right way. This means that the form of objects is neither perceptible, nor relevant, in the world of the earthworm.

The example of the earthworm is only one of many similar examples of trying to describe how an animal perceives its environment in von Uexküll's book. There are other examples describing the perception signs that are relevant to animals like sea-urchins, ticks, different birds, bees, hens and so on. According to Schroer (2021), "In asking the reader to stop and consider the world from the animals' points of view Uexküll explicitly tried to break away from the anthropocentric perspective that permeated the mainstream academic debate of his time" (p. 2). von Uexküll's research and his concept of *Umwelt* influenced the philosophy of both Heidegger and Merleau-Ponty, and is now considered pioneering work in considering a more-than-human world. However, von Uexküll's concept of *Umwelt* has also been discussed and interpreted in different ways, and some of his ideas of teleology and organisms unfolding due to an underlying plan of nature may limit the applicability of his ideas in current research (Schroer, 2021). Still, a recent publication in the journal *Integrative and Comparative Biology* revisits von Uexküll and addresses human biases in the study of animal perception (Caves et al., 2019). One of the biases is that we "we assume animals perceive sensory information the same way we do" (p. 1452). For instance, assuming that earthworms perceive forms of leaves as we do would be an example of such a bias.

In science teaching and learning, treating questions like *How do earthworms perceive their environment?* seriously may address anthropocentric biases in scientific practices. According to Schroer (2021), "understanding other worlds is not an exercise of making absolute and clear-cut claims about ontology but rather an acknowledgement of more-than-human world making as mobile, permeable, and necessarily partial process" (p. 145). Thus, following Schroer, to understand the world of an earthworm is not about making deterministic descriptions or explanations of their world, but rather investigating how the world (*Umwelt)* of the earthworm and other worlds "overlap and mutually constitute each other" (p. 140*).*

Tasks for students in primary school when working with the case of von Uexküll could be to investigate what kind of perception organs different animals possess, but also to engage in understanding the significance of these perception organs in the life of, for instance, an earthworm, a woodlouse, or a peacock butterfly. As Aristotle advocated for, to describe an animal is to describe both form and function of different parts, and how the parts serve the animal as a whole. The same applies to an animal's perception organs, i.e., investigating the physiology of sensory receptors is not enough, the students must also observe an animal's behavior and interaction with other living beings to understand the meaning of an animal's perceptual world. According to Caves et al. (2019):

> Overall, investigating the perceptual world of an animal is a complicated task. However, it is also rewarding, because the *Umwelt* provides a foundation for understanding why animals behave the way they do in a

> variety of contexts, yielding insights into the diversity and function of signals, how receivers exert selection on senders, how animals make decisions, and more (p. 1459).

Thus, trying to understand how living beings other than humans perceive their world in terms of their environment gives the students chances to explore various questions relating to topics like the organisms' physiology, ethology, and ecology. For instance, observing how a woodlouse uses its antennae to move around in an environment may lead to questions like: What are the important signs in the woodlouse's environment? Why are the antennae more developed than the eyes? How does a woodlouse perceive the difference between a maple leaf, which it likes to eat, and an oak leaf, which it doesn't? von Uexküll and his concept of *Umwelt* "argues against the notion of one objectively measurable world accessible through science and points to the polyphony of subjective universes that abound once careful attention is paid to their peculiar expressions and temporalities" (Schroer, 2021, p. 147). Such an approach has the potential to demonstrate to students a richness of both the phenomena in living nature and of scientific practices.

To use the case of von Uexküll as a teaching case in primary school, some issues need to be considered. According to von Uexküll, the *Umwelt* of animals "are revealed only to our mind's eye and not to our body's" (p. 43), and his bubble-metaphor also indicate an enclosure of the subject and a limitation to our ability to grasp the world of another living being. In science teaching and learning, I will argue that the students' embodied experiences and emotional involvement could and should be part of an approach to understand how non-human living beings perceive their world. In addition, the *Umwelt* of an organism can only be grasped by considering how the organism interacts with its environment and other living beings. For instance, the world of a peacock butterfly cannot be understood without knowing about its host plant, and the host plant mirrors aspects of nutrition and camouflage in the world of the larvae of the peacock butterfly. Trying to understand how a peacock butterfly, or an earthworm, perceives its environment would require imagination, but also an education of attention that builds on the students' own experiences of being a living body interacting with and being part of its environment (cf. Ingold). By practicing responding to and identifying themselves with other living beings in nature in this way, the students also practice an ethical attention (cf. Chapter 13).

As I have argued throughout this thesis, we, as human beings, can apply different modes of observations, and different contexts, questions, and former experiences decide what becomes significant in our environment of living nature. The case of von Uexküll opens to questions about whether this variability of perceiving the environment also applies to living beings other than humans. Schroer (2021) argues by the example of falconry, that for instance birds and humans can develop "partially shared *Umwelten* in which humans and birds learn to interpret the world and each other's movements through a shared set of communicative practices" (p. 143). Questions that arise are: How do subjective life experiences of different organisms (that go beyond their species-specific experience of their world) affect how they perceive their environment? In teaching and learning, how might students and non-human living beings co-learn and share processes of meaning making?

In relation to the typology of modes of observation presented in Part IV, I would classify the case of von Uexküll as a *participatory and empathetic* mode of observation that complements an anthropocentric perspective. Unlike the other four modes described earlier, such a fifth mode of observation invites the students to identify themselves with other living beings in a very concrete and fundamental way. Practicing this mode of observation is not only about how the students make sense of what they observe, but also how the students understand and respond to what is meaningful in the life of other, non-human living beings. As a teaching case, this fifth mode of observation not only expands and complements the other four modes of observations, but it also demonstrates a qualitatively different practice. This mode of observation acknowledges that the things in the world of both humans and non-humans do not have one single meaning that can be studied objectively, but rather many different meanings depending on who's *Umwelt* they are part of.

I will go on to describe my own modes of observation and meaning-making processes in this project.

15.2 Methodological reflections

> Not everything that can be counted counts and not everything that counts can be counted (attributed to Albert Einstein).

In this section, I will reflect on my experiences with the process of doing research in this project, and I will discuss the methods I used to collect and analyze data. Finally, I will summarize implications of my study and some topics for further research.

15.2.1 My modes of observation as a researcher

As described in Chapter 11, Linné wrote in the introduction to *Genera Plantarum*:

> I have selected certain and real, not vague and shaky features while describing the various parts of fructification. Others often assume taste, smell, color, magnitude (without [paying] attention to proportion). Such you will never see adduced by me, but only those four certain and firm mechanical principles: number, shape, situation, and proportion (Müller-Wille & Reeds, 2007, p. 569).

With this quote, Linné implies that only what can be measured or counted, matters, or is perceived as certain and real. As discussed in Chapter 14, about observational practices in school, if only what can be measured matters, then all the things that cannot be measured (quantitatively) do not matter. According to Eneroth (1986),

> In summary, the quantitative method therefore involves a frightening limitation of what can be investigated scientifically. With this method, you can only capture any quantifiable aspects of qualities, and preferably those that can be targeted with high precision (p. 35; my translation from Swedish).

If the purpose is to make a system of classification with general and categorizable criteria that everyone can agree on, counting petals and stamens of flowers makes sense. However, if the purpose is to recognize and describe a flower as we experience it, it is necessary also to describe all the qualities that cannot be measured, like its smell, color or transformation from bud to full flower. In the same way, in describing experiences with the phenomenon of observing living nature, as I have done in this study, not everything that counts can be counted (cf. the quote above). I have learned that the phenomenon of observing living nature has multifaceted qualities. How someone observes nature is influenced by their lived experiences, different modes of observation reflect ideas about science, and are affected by the context and culture. Qualitative research, as I see it, is an approach to describing all those things in human lived experience that cannot be counted or measured.

A process of crystallization

Qualitative research can be described as a process of crystallization (Denzin & Lincoln, 2011). As described in Chapter 9, the metaphor indicates that reality is complex and that phenomena can change when we study them. In a crystallization process, the crystal grows and changes, reflecting images on the outside and bending the light on the inside, and it can look different from different angles. This agrees with my own experience of the qualitative research process being a dynamic process where the qualities of the phenomenon of observing living nature being added or changing. Studying other teachers' and students' experiences with this phenomenon of observing living nature reflects new qualities, extending, and changing my own experiences with the phenomenon. In different modes of observation, applying the four teaching cases, the things in living nature may look different. For instance, a comparative mode of observation may direct the students' attention to things like the different forms of insect legs, while a holistic and aesthetical mode of observation may direct the attention to things like the colors of butterflies and their changing and entangled nature.

Exploring the observation of living nature with a phenomenological approach, I have looked for the extraordinary in the ordinary in my own experiences, in the experiences of historical pioneers, and in teachers' and students' experiences with observing living nature. Looking for the extraordinary in ordinary experiences is part of a phenomenological attitude of wonder and of challenging what is taken for granted (van Manen, 2016a, pp. 222-223). The aim of such an attitude is to "gain a deeper understanding of the nature or meaning of our everyday experiences" (van Manen, 2016b, p. 9). For instance, I have looked for and found the extraordinary in statements like “if you are looking at real plants [in nature], you get more than a picture, since then you can turn the plant around and look closely” and discussed the meaning of such an experience.

In my study, I started by looking for typical modes of observation in the history of exploring living nature in the first phase and went on to investigating teachers and students in a case study in the second and third phases. Selecting cases and extracting modes of observation in four historical cases in phase 1 made the phenomenon of observing living nature richer and more nuanced to myself and influenced my own teaching and further research in the next two phases. The cases reflect essential qualities of observing living nature in themselves, but they also expanded both my own, and the teachers’ and students’ experiences with the phenomenon. The teachers’ and students’ responses to these cases in the continuing education course and in the classroom, in turn, added new qualities to the phenomenon of observing living nature in teaching and learning. Experiences from Phase 2 influenced how the teachers implemented the cases in the classroom studies and how the interviews with the students were conducted and analyzed in Phase 3. In the end, a discussion of the meanings of these experiences pointed to two topics for further discussion: ethical attention and sensible observational practices in exploring living nature in primary school. The discussion of these topics was a result of the whole process and can be seen as the fourth phase of my study. With Ingold (2018) words, I might say that I went “along the sensible path of continuous variation” (p. 41), trying to be receptive and responsive in the process.

Thus, all phases in this project describe a dynamic process, during which the meaning of experiences with observing living nature in teaching and learning science developed and transformed along the way. This implies that the project was action oriented. However, as discussed in Chapter 9, the aim of the case study was to arrive at a description of qualities with the phenomenon under investigation. The aim was not directly to improve teaching practices by means of reflective cycles, as would be the case in an action research project (Sáez Bondía & Cortés Gracia, 2021).

Making ‘thick descriptions’

I have argued that the observational practices described in my four cases represent different and complementary ways of knowing: I. A comparative mode of observation to find essences, II. A holistic and aesthetical mode of observation to make accurate descriptions, III. A systematic and analytical observation to make systems of classification, and IV. An explanatory and synthetical mode of observation to formulate theory. In addition, I have indicated a possible fifth case: V. A participatory and empathetic mode of observation to investigate multiple meaning-making processes and invite the students to identify themselves with other living beings in a very concrete and fundamental way. These different ways of knowing lead to different and complementary kinds of knowledge about living organisms in nature. In the following, I will discuss how these different ways of knowing might apply to my modes of observation in this project.

The phenomenological approach in my case study seems to be a parallel to practicing a holistic and aesthetical observation (cf. Merian) to make accurate and detailed descriptions of natural phenomena. Merian wished to "draw and describe them [the butterflies] all according to nature" (Friedewald, 2015, p. 120) and she made holistic descriptions. Her pictures demonstrate an aesthetical appreciation of the butterflies as phenomena and depict a holistic story of growth, transformation, and interactions with other living organisms. A phenomenological research approach can be described as wishing to understand phenomena "from the actors' own perspectives and describing the world they perceive" (Kvale & Brinkmann, 2015, p. 45). In my study, I have made holistic descriptions in terms of "thick descriptions" (Creswell & Poth, 2018, p. 245). I have strived to be accurate and detailed, and to paint a whole picture of the teachers' and students' experiences with practicing observation of living nature in primary school. According to Denzin (2001), thick descriptions present both detail and context, and "the voices, feelings, actions, and meanings of interacting individuals are heard" (in Creswell & Poth, 2018, p. 245). In my descriptions, the voices of both the students and teachers are heard equally, and I show how these voices occasionally interact with or challenge each other. In naming, describing, and discussing themes, like "Teaching is to explain", I have tried to condense meanings. The themes do not necessarily represent essences, but rather what I perceive as significant qualities or issues to explore and discuss about the phenomenon under investigation. I have for instance discussed the meaning of a teacher experiencing "a lack of facial expression in nature", or the students experiencing that there is "something more to the living", and I have also showed how these experiences interact and challenge each other. Together, the themes and the discussions of meanings hopefully constitute a thick description of both the students' and the teachers' experiences, and their interactions; a description that paints a holistic picture of these experiences for the reader.

Pointing to a meaning is different from pointing out the meaning by imposing an external framework or a theory (van Manen, 2016b, p. 26). To explain an experience theoretically would be more in line with an explanatory and synthetical mode of observation (cf. Darwin/Wallace). In such a mode of observation, I would have gathered a lot of observations and data about, for instance, teachers' experiences with "a lack of facial expression in nature", and then tried to synthesize these experiences and formulate a theory that could explain all such experiences. However, in my study, I am not looking for that kind of explanation or generalization, I rather try to unpack and explore the multifaceted meanings of observing living nature and expressions like "a lack of facial expression in nature".

A discussion of my interpretations

Merian's pictures were, among other things, a result of her lifelong experiences with collecting butterflies and her skills as a painter. Likewise, my descriptions of the teachers' and students' experiences with observing living nature are a result of my former experiences as a biologist, student, teacher, and teacher educator, as well as my skills as a researcher. This means, that although striving to be accurate and to make thick descriptions of lived experience, my descriptions are not objective in the sense that another researcher would arrive at the same descriptions, or the same themes. However, as I understand it, being objective in that sense is not the purpose of qualitative research. As referred to in Chapter 2, according to Daston and Galison (2010),

> To be objective is to aspire to knowledge that bears no trace of the knower – knowledge unmarked by prejudice or skill, fantasy or judgement, wishing or striving. Objectivity is blind-sight, seeing without inference, interpretation or intelligence (p. 17).

In the interpretation of meanings, I use my knowledge and former experience, otherwise it would be a form of "blind sight" (cf. Daston & Galison). I have chosen a phenomenological approach to the research in this project that affects how I understand the meanings of the teachers' and students' experiences and statements.

To point to meanings of experiences, such as perceiving "a lack of facial expression in nature", means that I make interpretations of another person's experiences. As a researcher, I point to meanings that may both confirm and challenge the participants' experiences (Henriksson, 2012). The meanings are my interpretations, and the participants may not agree with them, or the interpretations may not be meaningful to them. To amend for the possible distance between my interpretation and the participants' understanding of their own experiences, I asked all the teachers, in their second interview, to comment and interpret some of the statements that I had found significant in the first interview. For example, the teacher who perceived "a lack of facial expression in nature", commented his own statement like this:

> Me: If you were to interpret your own statement, what do you think the statement is saying?
> Thomas: It says that one must learn to observe ... and that certain things are more natural for humans to observe, including their own species. (…) For modern people, it's people you meet. Buildings and situations in the traffic you see. If you're going to extrapolate it [the above-mentioned situations] to nature, you would have observed nature in a different way if you had lived in it [nature][sss].

The teacher's reply shows that asking the participants to interpret their own statements may add another layer to what was said earlier, and thereby broaden the meaning of the statement. According to Thomas's own interpretation, his experience of "a lack of facial expression in nature" has something to do with our modern way of living, in addition to a lack of ability to recognize other beings than humans. Observation in nature is something one must learn, and he indicates that we would have observed differently if we had lived in nature. This teacher's interpretation of the meaning of his own statement demonstrates how such an interpretation can elaborate on the meanings of the teachers' experiences that may add to my interpretations as a researcher in this project.

In qualitative research, it is significant to consider questions like: Who owns the data? Whose interpretations counts? (e.g., Mertens & Ginsberg, 2009; Wertz et al., 2011). When I incorporate the teachers' own interpretations, it is a way to share power in the research process. In many instances, qualitative research has undertaken "a more dialogical and collaborative relationship with research participants" (Wertz et al., 2011, p. 84). However, according to Wertz et al. (2011), the interpretive authority rests with the researcher. As a researcher, I have "an authority that is developed and cultivated by education, training, and critique" (p. 363). For instance, I use a phenomenological approach, building on the works of Heidegger, to interpret and discuss how things in living nature come into being for the participants. The meaning of the expression that there is "a lack of facial expressions in nature" is interpreted in this context. Such a phenomenological approach consists of conceptual tools and analytical methods that the participants cannot be expected to be in possession of. Still, as a researcher, I am subject to authority beyond myself "in the forms of both new data and in the criticism and alternative analyses of other scientist" (Wertz et al., 2011, p. 363). Thus, my modes of observation in this project lead to descriptions and interpretations that rest upon my lived experience, skills, and theoretical knowledge, but that have been shared with both participants and other researchers during the research process for validation.

The above discussion of interpretation leads to the notions of validity and reliability in the research process and of the knowledge claims. I understand validity and reliability in my study as formulating a clear phenomenon for investigation, making rich descriptions of the empirical material, and providing interpretive depth grounded in primary literature and phenomenological procedures of analysis. My understanding builds on the phenomenological quality criteria formulated by van Manen (2016a): "heuristic questioning, descriptive richness, interpretive depth, distinctive rigor, strong and addressive meaning, experiential awakening, and inceptual epiphany"(p. 355-356). According to Kvale and Brinkmann (2015), "the validation depends on the quality of the craftsmanship of the investigation, where the findings must be continuously checked, questioned and theoretically interpreted" (p. 278; my translation from Norwegian). Understood this way, *the validity* of my thesis must be judged by evaluating the entire research process and whether I, with the applied questions and methods, actually investigated what I had set out to investigate. To make such a judgement by others possible, I have tried to provide clear accounts of my own preconceptions, theoretical foundation, research approach, and methods for collecting and analyzing data. *The reliability* depends on whether my descriptions and interpretations throughout the process are trustworthy and consistent, and on whether the results may be reproduced in other contexts (Kvale & Brinkmann, 2015). However, in my phenomenological study, I have presented various viewpoints and investigated multiple meaning-making processes with the phenomenon of observing living nature, and not necessarily presented results that can be reproduced in another context. Wertz et al. (2011) suggest that in qualitative research "validity exceeds and takes priority over reliability. That is diverse viewpoints and analytic findings enhance the truth of our knowledge rather than compromise it." (p. 385). By presenting various viewpoints, my approach here seems to align with the fifth case and its participatory and empathetic mode of observation to investigate multiple meaning making processes. In the research process, I have tried to understand and respond to what is meaningful in the students' and teachers' experiences with observing living nature.

The notion of reliability does not only have a methodological meaning, but also has a moral meaning (Kvale & Brinkmann, 2015). I will elaborate on this meaning in the next section about ethical attention in the research process.

15.2.2 Ethical attention in the research process

In Chapter 13, I described a triangle of ethical attention in teaching and learning observation of the phenomena in living nature (Figure 14). I have argued for and elaborated on three conditions for ethical attention in this triangle, one for each of the participants:

1) The teachers acknowledge the students as subjects and practice overcoming their own blindness towards the phenomena in living nature.
2) The students practice responding to, and identifying themselves with other living beings, rather than just identifying them.
3) The phenomena in living nature can be disclosed and invite both teachers and students to pay attention.

Researching these relationships adds a fourth condition above the triangle of ethical attention (Figure 18). As a researcher, I must practice an ethical attention towards the students, the teachers, and the phenomena in living nature. I must practice silencing myself and be receptive and responsive to all three participants in the triangle and to the relationships between them. In the following, I will argue that the fourth condition for practicing ethical attention in these relationships is:

4) The researcher practices an attitude of silencing themself and being responsibly engaged with the other participants, and of paying attention to each of the participants and to the details, context, and complexity in their mutual relations.

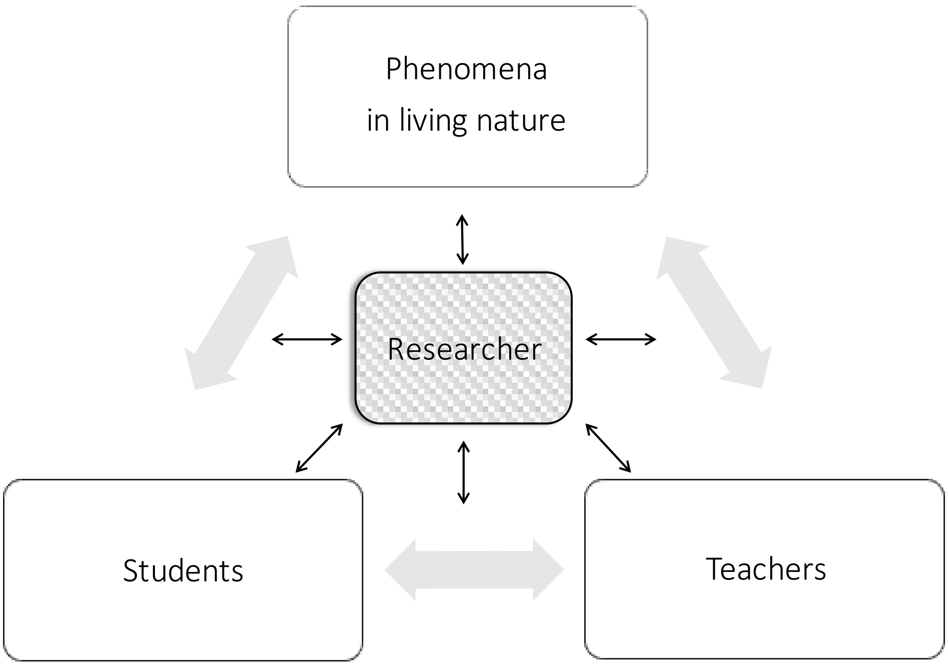

Figure 18: The researcher practices an ethical attention towards all three participants, as well as their mutual relations.

My study has been approved by *Norwegian Centre for Research Data (NSD),* and I have collected informed consent by all participants. According to the rules and guidelines by NSD, about collecting, processing, and storing personal data, my project is ethically justifiable. However, as a researcher I must also act ethically and make sure that I do no harm. Ethics may be understood in terms of theories and rules, like deontological ethics or utilitarianism. However, according to Aristotle's ethics of virtue, ethics is primarily understood as practical wisdom (*phronesis*) (Kvale & Brinkmann, 2015, p. 101). In *Nichomanian ethics,* Aristotle says that "the judgment depends on perception"[39] (Aristotle, 2001, p. 213; 1109b). According to Nussbaum (1985), Aristotle argues that practical wisdom…

> … is concerned with ultimate particulars (…) and that these particulars cannot be subsumed under any episteme (a system of universal principles) but must be grasped with insight through experience (…). In praising perception, he is praising the grasping of particulars contained in this sort of experienced judgement (p. 68).

In my understanding, the ability to judge well lies in the attention to all the qualities, details, and complexity in the situation. Nussbaum (1985) further describes what she sees as "a perceiving agent" in this context:

> Being responsibly committed to the world of value before her, the perceiving agent can be counted on to investigate and scrutinize the nature of each item and each situation, to respond to what is there before her with full sensitivity and imaginative vigor, not to fell short of what there is to be seen and felt because of evasiveness, scientific abstractness, or love of simplification. The Aristotelian agent is a person whom we could trust to describe a complex situation with full concreteness of detail and emotional shading, missing nothing of practical relevance (p. 84).

What Nussbaum describes is an ideal for how a researcher can act ethically and apply an ethical attention in their research. As elaborated in Chapter 13, an ethical attention entails a process of unselfing, where you absorb yourself with the world (instead of being absorbed with yourself) and are receptive and responsive to the world around you. Being receptive means that you pay attention to both details and contexts, and being responsive means that you adjust your attention in some sort of dialogue with what you are investigating.

As the teachers and the students in their observational practices, I, too, as a researcher have to practice an ethical attention. The phenomenological attitude of suspending or bracketing my preconceptions (*epoché*) seems to be a parallel to

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[39] The full quote is: "Still, we are not blamed if we deviate a little in excess or deficiency from doing well, but only if deviate a long way, since then we are easily noticed. But how great and how serious a deviation receives blame is not easy to define in an account; for nothing else perceptible is easily defined either. Such things are among particulars, and the judgement depends on perception."

silencing myself in an ethical attention to let others be heard (cf. Fredriksson & Panizza, 2020). Likewise, the phenomenological attitude of wonder, openness, and concreteness (cf. van Manen, 2016a, p. 223), seems to be a parallel of being receptive and responsive to the particular in the situation. However, for me to apply an ethical attention in the research process, such an attitude must be grasped and practiced through experience. Being a PhD student means that I am not yet experienced as a researcher, and my ability to judge well by careful attention will probably develop as I engage further in doing research. The meaning of ethical attention in observational practices was not clear to me when I started this project, neither in terms of observing, e.g., a bird in nature, nor observing students in the classroom. However, I have tried to apply a phenomenological attitude throughout my research process that hopefully has helped me to conduct research that was according to an ethical attention.

In my project, I observed and interviewed children, and this puts an even stronger emphasis on the meaning of ethical attention. Comparable to sitting completely still to observe a bird, to let it show itself, and not scare it away, I also must act carefully when engaging with children in my research. To engage responsibly with children in research means putting their needs first and not doing any harm (NESH, 2022). Furthermore, the UN's convention on the Rights of the Child state that all actions concerning children should be in the best interest of the child (article 3) and that children have a right to be heard in all matters affecting them (article 12) (Unicef, 1990).

In my study, the students' parents signed the consent on behalf of their children, but the parents were encouraged to involve their children in the decision about participating in the project. In addition, I informed all students about the project, and the six students I interviewed were asked specifically about whether they wanted to participate in the interviews. To adjust to the students' needs and wellbeing, I conducted short interviews of about 10 minutes during their classes, and not during their breaks. I adjusted the interviews to each student, and in the interviews, I tried to be responsive to what the students told me. Responding to the students' needs and letting them participate in the research on their own terms are examples of being responsibly engaged with the students as a researcher. However, in doing research with children there will always be uneven power relations. To what degree it is possible to actually do research *with* children, or represent children's voices in research can be discussed (Lane et al., 2019). For instance, it is possible that the students agreed on being part of the interviews mainly to please me, not because they want to participate in the project and let their voices be heard. To amend for uneven power-relations, an ethical attention towards the students in the process is even more important, in addition to my ability to reflect on the processes that produce 'the students' voices'. When I represent the children's voices in my thesis, it should be emphasized that these representations are constructed by me, rather than masking issues of power dynamics with terms like "participatory" and "co-researcher" about the role of the students (Lane et al., 2019).

Other vulnerable participants in this project are the non-human living beings that were observed. For instance, the earthworms that were collected outside and put in a terrarium to be observed by the students in the classroom could not consent to being part of this project. It can be argued that this lack of consent makes me as a researcher even more responsible for the earthworms' well-being (Fredriksen, 2020). As with the other participants in the study, I must responsibly engage with the earthworms by responding to their needs and performing the research on their terms. Krzywoszynska (2019) argues: "Central to relational ethics is the practice of attentiveness – of attending to the non-human other, of becoming response-able to them" (p. 664). The earthworms that participated in this study were attended to. They were put in a terrarium together with living soil and leaves, and the terrarium was regularly watered. After some weeks, the teachers emptied the terrarium and the earthworms returned to their original environment in the schoolyard. However, the process of being dug out of the soil and placed in a terrarium may have been potentially harmful to the earthworms, and the indoor climate was probably both too hot and too dry compared to their natural environment. In all research, potential harmful consequences must be weighed by the potential benefits of doing the research. In terms of relational ethics, the students attending to the earthworms may have possible long-term positive effects for both students and earthworms.

15.3 Topics and questions for further research

The phenomenological approach in this study shows that teaching and learning about living nature is not only a question of knowledge and skills, but also about how in these processes the students, the teachers, and the other living organisms come into being. We need further research on the meaning of these existential and ethical relationships between teachers, students, and living nature in science teaching and learning. This could include research that goes beyond the conceptual and cognitive dimensions of learning science and includes the students' embodied experiences and emotional involvement in the exploration of living nature. In further research, it is especially urgent to consider the consequences of teachers' and students' current lack of attention to the diversity of living beings and elaborate on how the teachers can meet this challenge in their teaching. This lack of attention is demonstrated as a blindness to living nature in several studies and as a loss of knowledge about local flora and fauna among both students and teachers (e.g. Allen, 2003; Ballouard et al., 2011; Buck et al., 2019; Knapp, 2019; Schussler & Olzak, 2008; Yli-Panula & Matikainen, 2014). Some studies show the potential to enhance students' attention to plants through personal encounters, observations, and guided explorations (Krosnick et al., 2018; Lindemann-Matthies, 2002; Nyberg & Sanders, 2014). However, qualitative studies on the students' embodied experiences and emotional involvement in these practices are still limited, although some studies investigate, for instance, the connection between students' emotional experiences and place in interacting with nature (Kahn & Thea, 2017; Lanouette, 2022).

I call for further research on the connections between different modes of observation and the students' embodied experiences and emotional involvement in these practices, as well as their cognitive conceptions about the phenomena in living nature. And further, I call for research that addresses how teachers can meet the challenges of allocating the students' limited attention resources towards the phenomena in living nature. Several studies indicate what might be called an attention crisis. One study speaks of "a more rapid exhaustion of limited attention resources" measured at a population-level (Lorenz-Spreen et al., 2019, p. 1). Another study speaks of how increasing numbers of alternative digital applications on tablets, mobile phones, and desktop computers, can lead to a "cognitive overload that can impact their [the users] attentional control" (Rieser & Furneaux, 2022, p. 3). These studies are quantitative studies at a society-level, measuring how people allocate their attention to different online applications. Exactly determining how such technology influences attentional processes and learning in the brain has proved to be complicated, and may have "either positive or negative effects on cognition" depending on the situation (Lodge & Harrison, 2019). However, none of these studies consider the existential and ethical consequences of a potential "exhaustion of limited attention resources" and the loss of embodied experiences in nature due to digital technology.

I briefly summarize some topics and questions for further research:

1) **Expanding the four modes of observation by a fifth teaching case demonstrating a participatory and empathetic mode of observation,** such as described in the first section of this chapter. Questions are: How do students in primary school experience and respond to such an approach? How do they emotionally involve with the phenomena in living nature? How may students and living beings other than humans co-learn and share processes of meaning making?
2) **Expanding practices of observation by using an open observation** where the students observe without a predefined mode of observation. Questions are: What do the students notice? What questions do they ask? How do the students use their bodies and senses in exploring and responding to the phenomena in living nature? Do new modes of observation develop?
3) **The allocation of the students' attentional resources in science teaching and learning.** Questions are: How do both teachers and students in primary school allocate their attention towards the phenomena in living nature? What potentially hinders such an allocation? Do experiences through digital media replace or mediate experiences in nature? And if digital media do replace or mediate experiences in nature, how do these digital experiences affect both how the students and the phenomena in living nature come into being in these experiences?
4) **The role of the teachers in exploring living nature with students in primary school**. My study points towards a need for educating teachers. In some cases, the teachers in my study demonstrate a lack of knowledge and recognition of the phenomena in living nature themselves and have preconceptions that possibly constrain the observational practices for their students. This points towards what may be a blind spot in teacher education. For instance, studies across several universities in Europe emphasize the importance of teacher students gaining experience with enacting meaningful teaching activities about biodiversity with students in

school, and not only filling their own 'knowledge gaps' (Lindemann-Matthies et al., 2011; Lindemann-Matthies et al., 2009). Questions are: How to educate teachers so they overcome their own blindness to nature? How do teacher students experience cases that demonstrate different modes of observation? How can teacher students participate in a meaningful dialogue about both the students' experiences and the phenomena in living nature? How can teacher students engage responsibly with both students and the phenomena in living nature?

15.4 The nature and meaning of observing living nature

The overall research question I set out to answer in this thesis was: *What is the nature and meaning of observing living nature in science education in primary school?*

In the previous chapters I have described the teachers' and students' diverse experiences with observing living nature. I will summarize the nature of the phenomenon of observing living nature with the following five qualities: *First*, observing living nature invites students and teachers to constantly make new discoveries. The phenomena in living nature are rich and diverse and seem to reveal themselves in observation under the right conditions. *Second*, observing living nature is both a cognitive and embodied practice. In the act of observing, there is an interplay between knowing what to look for and paying attention by using one's senses. *Third*, observing living nature is a relational practice. Living nature provides manifold experiences, but to experience and respond to what living nature offers, both teachers and students need to educate their attention. *Fourth*, as a scientific practice, observing living nature is complex. Different modes of observations lead to different types of scientific knowledge. *Fifth*, observing living nature has existential and ethical implications for both students and teachers. Practicing different modes of observation is not just about what kind of knowledge the students or teachers get, but how the things in living nature, the students, and the teachers come into being through these practices.

When it comes to the meaning of observing living nature, there is not a single meaning, but many. My research also shows that the meanings may change and develop. As a child, one's relationship with living nature is open an undecided, and the meaning of observing living nature is not defined. Observations will probably be playful, imaginative, and aesthetic. As a student, the meaning of observing living nature will gradually become more defined and be about noticing things like differences and nuances of variation in living nature, making systems of the entities in nature, describing entanglement and interconnections, and making explanations. As a teacher, the meaning of observing living nature is even more complex and involves both observations of the phenomena in living nature and the students experiencing them. In addition, my four cases from the history of science demonstrate that the meaning of observing living nature in science has changed through time and thus depends on the questions that are perceived as relevant to ask in a certain context.

By phenomenologically investigating the teachers' and students' lived experience with observing living nature, I have provided written descriptions of the nature of these experiences in terms of themes and made interpretations to portray the multifaceted meanings of these experiences. To me, the meaning of observing living nature in the context of teaching and learning science in primary school has grown deeper throughout the research process. More than just gaining knowledge of living nature by different modes of observation, I now understand the meaning of observing living nature as an education of both the teachers' and students' attention to bring the phenomena in living nature into existence and to responsibly engage both teachers and students with these phenomena.

15.5 My lived experiences 2.0 – Being a teacher educator and becoming a researcher

In the past five years, I have been a teacher educator in addition to being a PhD student. Every spring semester I teach biology in the teacher education program for students who are going to be science teachers in primary school. I will here briefly describe a project I have been doing with my students that is inspired by my research into the practice of observing living nature.

My research on the meaning of paying attention to living nature led me to ask how I as a teacher educator facilitate the teacher students' experiences with these phenomena in my own teaching. In teacher education, the students need to gain experience both with exploring the phenomena in living nature themselves, but also with exploring the students' experiences with these phenomena. The question is how I can design a teaching practice that incorporates and facilitates experiences at both these levels. I decided to try out a project where the teacher students do at least three observations in nature during the spring semester, and then prepare and conduct an interview with primary-school students who have done the same type of exercise. The teacher students get to choose a spot where they want to do their observations, and I tell them to use a field journal to document their observations, but not how. I explain that part of the exercise is to figure out how they want to describe and document their observations in the field journal. The overall topic for the observations is changes in nature, going from winter to spring. At the same time, in cooperation with a teacher in primary school, we arrange for a class of students in fourth grade to do the same type of exercise.

To prepare themselves for the task of observing in nature, the students carry out some exploratory exercises on campus. In the first exercise, the students explore seeds. In the lab, they can study many different types of seeds, such as peas and beans, but also seeds from wild plants such as rosebay willowherb, maple trees, and creeping thistle. There are also various fruits such as apples, avocados and tomatos. In addition, there are pictures, drawings, and paintings of seeds, or things related to seeds. There is a text by Theophrastos, a contemporary of Aristotle, that describes different types of fruits and seeds. Altogether, these different materials give the students many different approaches to the topic. They can choose which material they want to explore, but they must observe thoroughly and describe what they see. After drawing and describing, the students write down their own questions, thoughts, and ideas about what they had investigated. All the students' papers are handed in, scanned, and shared on a digital platform used for teaching the same day. The students gain access to each other's work, and thereby an insight into a variety of approaches and good questions on the topic of seeds. Many of the questions the students ask turn out to be good starting points for further exploration. All students also write a personal log about their own experiences, which is shared with me as their teacher.

In the second exercise, I increase the complexity, and the students explore life in a meadow. In this exercise, life in the meadow includes all the plants and animals living there, but also how humans experience and interact with the meadow. This time, the students start by watching one of three short films, which in different ways depict life and interactions in the meadow. In the lab, there are dried specimens of plants and insects, and various drawings and paintings of meadows and of human interacting with meadows. There are photos of students making observations in the meadow (from my own PhD-project) and copies of some observation notes made by students in primary school. In addition, there are excerpts from two articles about the double role of the science teacher (Østergaard, 2011), and the gesture of teaching (Biesta, 2022a). Together, this material gives the students several approaches to explore the life and interaction in the meadow. In the same way as described in the previous exercise, the students observe and describe the selected material thoroughly, before they begin to formulate their own thoughts, ideas, and questions. The aim of the exercise is for the students to develop a research question about observation and the use of field books in science teaching, which they would like to investigate further. The students submit answers to the tasks they are working on, as well as a personal log, at the end of this day. In the afternoon, I read through the students' submissions and respond to them. I pick out some of the students' statements and share them with the class for discussion in the lecture on the following day. The students discuss and work to further develop a research question about the primary school students' experiences with making observations in nature. The research question will form the basis for the interviews with students in primary school at the end of the semester.

Finally, the students write an exam paper based on their own experiences, the conversation with the students in primary school, and literature from the syllabus. In the assignment, they discuss the ways in which such an observation task can contribute to an education for sustainable development, and how observation and use of a field book can be part of an exploratory science teaching for students in primary school. Documentations from their field-journal are attached to the exam paper.

What I have learned from both being a teacher educator and becoming a researcher in this project, is that the teacher students need to relate to both the phenomena in living nature and the primary school students experiencing these phenomena. For the teacher students to develop meaningful concepts, theories, and models about both science and science teaching and learning, they, too, must first be given the opportunity to make their own experiences. For me as someone who is responsible for the education of the teacher students, I have with the project described above tried to let the teacher students develop their own questions and ideas about observing living nature. The purpose of the project was to give the teacher students an opportunity to discover the richness of the phenomena in nature and hopefully experience a sense of wonder as described in the first chapter of this thesis. However, more than that, in an open observation they must find their own way of making descriptions, and by letting the teacher students ask their own questions and formulate their own thoughts, they learn to respond to these experiences as individuals. In addition, in conversation with students in primary school and with their exam paper, the teacher students must consider the meanings of such experiences in a context of teaching and learning science. In my experience so far, the teacher students find these exercises a bit strange and difficult to begin with, but they gradually grow into this way of investigating living nature. In the exam paper, they demonstrate that these experiences have given insights that are essential to them, both in terms of very fundamental discoveries like buds growing into leaves and the appearance of birdsong in the spring, and in terms of their role as future teachers. One of the students writes in the log:

> We as teachers must give students knowledge, but it is also important (…) that the students themselves get to explore and learn things in this way [observing and responding to the phenomena in living nature]. Perhaps we [as teachers] can also learn something from the students' perspectives on things? [ttt]

In the process of becoming a researcher, I have developed my competence as a teacher educator by gaining a deeper understanding of observation as a relational practice between students, teachers, and the phenomena in living nature. I see the teacher students come into being as teachers-to-be by making their own discoveries of the experiential richness that the phenomena in living nature may provide, both to them and their students in primary school. To me, exploring the primary school students, teachers', and teacher students' manifold experiences with living nature has promoted an ongoing education of my own attention that seems to open to ever more nuances in these relational practices.

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Original quotes from the transcripts in Norwegian

[a] Thomas: Det er jo vanskelig å få med når en er ute og observerer i naturen (på en måte) for en er jo mye mindre vant med det sjøl, du ser ikke noe ansiktsuttrykk eller bøyd nakke eller ...

[b] Tom: (Nei, jeg gjør ikke det ...) Da er det jo ting som kan være vanskelig, men da prøver du se på om de ser like ut ... (det også kan jo ha ...) Hvis en ser på to ender som ser forskjellig ut, tenker du det må være forskjellige arter, men så er det bare ho og hann, (sånne ting, men nei jeg vet ikke ... du ...) jeg vet ikke, en art ... du har jo lært noen arter (, du har jo lært litt om arter og så ...) Hvis de ser like ut så kanskje det er samme art, så finner du plutselig ut at disse eiketrærne er jo ikke samme art, for den ene er sommereik og den ene er vintereik, (... åja ...) Så da er jo spørsmålet hvor små skal forskjellene kunne være for at det er to forskjellige arter. Jeg vet det er noen sopper som jeg mener kanskje burde være forskjellige arter, fordi rødnende fluesopp har jeg sett to veldig forskjellige, du har en som er mer rosa og hatten detter lett av og en som er mer mørk og hatten sitter mer fast. Det er jo to helt forskjellige ting, klassifisert som samme arten, skulle de har vært to forskjellige arter? Jeg vet ikke, men hvem skal bestemme det?

[c] Lisa: Det jeg sitter igjen med er jo at det liksom naturen ..., (det er så stort,) det er jo liksom så stort at vi ikke klarer å tenke oss det. Det er liksom litt uendelig, litt sånn som når du dykker, at du hele tiden ser noe nytt og så ser du noe og så ser du noe nytt, du ser bare akkurat det foran deg, så kommer du tilbake og så ser du noe nytt. Så det ..., det sitter jeg igjen med. Det er alltid noe mer bak der.

[d] John: Altså, det er jo å få grunnlaget på en måte, at det ikke blir bare egne meninger og synsinger, men at de går inn og ser på det helt konkret og hva er det som faktisk er ... det faktiske ... Tenker jeg.

[e] Lisa: (Ja. Jeg tenkte egentlig ikke på noe konkret, jeg tenkte bare sånn generelt, fordi hvis du ikke ...) Du må vite litt hva du skal se etter, så du ikke bare ser etter alt som ikke har noen betydning.

[f] Thomas: Hvis du skal observere noe så er det greit å bli enige om på forhånd hva vi skal lete etter, og da er det jo viktig (tror jeg) at elevene får et eierskap til det da, at de har vært med på å bestemme hva vi skal lete etter.

[g] Tom: Der hvor vi bare satt stille i naturen og hørte og så på ting følte jeg ble for hippie for min smak. (Som sagt rasjonell ...)
Jeg: Du må fortelle hva som ligger i det
Tom: Det er litt vanskelig å beskrive, men det er litt sånn …, hva skal en kalle det, ... det blir litt sånn sitte og lytte til naturen, spirituelt ..., vet ikke. Selvfølgelig en måte å observere på det også, og som du pekte ut (så får du jo) ... du legger merke til ting på en ny måte og du får sammenligne to ulike biotoper ... Men jeg liker det mer konkret. (Nå ser vi på denne her. Nå studerer vi denne her, nå ser vi på hva som er relevant her).
[h] Tom: Så er det jo det argumentet med at hvis du skal forske på noe nytt noe da vet du ikke hva du skal se etter, for da må du jo se nytt på ting.

[i] Lisa: Da forklarer du mer, den har sånn og sånn hofter, eller dette dyret har følehorn, så må den andre da gjette da hvilke dyr det er, hvis han klarer å finne ut det da ... Men det blir jo ikke sånn en forklaring, det blir en beskrivelse av hvordan det ser ut. Men det kunne jo ha vært forklaring også hvis en forklarer egenskapene ... Da er det ikke bare beskrivelse, ... den fanger fisk med nevene, (den sover ...) altså den sover om vinteren i hi. Det er jo en forklaring, ikke bare en beskrivelse.

[j] Victoria: Kanskje litt sånn vi jobba med på det kurset ... Vi har beskrevet ... bare for eksempel å lage en bok for eksempel, beskrive planter eller et insekt, og egentlig ville det vært fint å tegne, det syntes iallfall jeg.

[k] Victoria: Det er mange elever som hadde kanskje likt det enda bedre da, mange som synes det er gøy å kunne lage ting og tegne og blir veldig motivert av når noe ser fint ut (... så tror også det). Det gir en litt annen inngang til naturfaget. Så er det jo en måte å lære på (man ...) De fleste barn er jo veldig visuelle da. Man husker bedre hvis man har lagd noe, eller tegnet noe sjøl. Husker kanskje farger bedre enn antall klør for eksempel (så husker de kanskje fargen bedre ... det jeg kan tenke meg ...) Naturen er vakker, man får et litt annet forhold til naturen også da.

[l] Thomas: Så da får en jo på en måte sett nøyere på det når en skal koble hånda inn ..., det har vel med å koble sansene sammen kanskje, da må du bruke både øyne og hånd, enn hvis du bare ser.

[m] Tom: Det er fin måte å få observert ting på for du må se litt nøyere på tingene hvordan det egentlig ser ut, iallfall når du påpeker det at de ikke bare skal bruke det bildet de har i hodet fra før

[n] Tom: Når man observerer bruker man flere sanser, man gjør det. Man tenker gjerne bare synet når man observerer, observasjon med øynene, men man kan observere med ørene, nesa, munnen også, så det er jo innenfor samme. I dag når vi samlet blader, selv om vi skulle samle løvtrær, så fant vi engsyre, og da fikk de smake på engsyre ikke sant, og det gjør tinge litt spennende, så det henger jo sammen med å observere og bruke flere sanser, men for å gjenkjenne et tre trenger vi utgangspunktet bare en sans, man trenger bare øynene ikke sant. Men hvis det er noen trær som jeg vet, sånn som alm, så kjenner du på almebladet, og da har liksom å ja, da kjenner du det, da husker du kanskje det at det var den som kjentes litt sånn ut, det kan jo være alm, flere sanser, da får du flere knagger å henge det på.. Ja, det tenker jeg.

[o] Thomas: Jeg tror jo at observasjon kan skape undring og fascinasjon for livet på en måte (, og der også ...) I undring ligger det jo spørsmål da, at en ved å observere kan i fellesskap komme frem til spørsmål som er spennende å jobbe videre med. Men det er jo vanskelig å lage gode spørsmål (og det er vanskelig å lage spørsmål som en kan jobbe videre med ...) Men observasjon er jo viktig i så måte tenker jeg. (s.4)

[p] Lisa: Ja egentlig ..., men mest på sånn, mye på et sånn sosialt nivå ..., hvorfor slo du han eller ikke sant.. Fordi han tok ballen min bort, men da må jeg forklare deg at det gjorde han ikke fordi ... han gjorde det fordi det noen annet skjedde. Man forklarer jo hele tiden, å være lærer er jo å forklare. I sosiale

sammenhenger, men også rent faglig forklarer du jo hvorfor ting er som de er, hvorfor må man bøye et verb, man må jo forklare verden, alt må forklares.

[q] John: Mye av det vi holder på med når vi har eksperimenter i fysikk og .... så går det jo på å forklare, og det er jo det ..., det er jo mye der vi ligger, så det er det ikke tvil om.

[r] John: Altså vi har, vi hadde senest her vi laget en vannrakett som vi skjøt, ikke sant, hvordan dette fungerer, fysikken der, og vi har hatt ja ... Alt fra tyngdekraft og alle mulige sånne ting, det er jo mye å forklare ting hvordan de er.

[s] Victoria: For eksempel hvorfor en vannflaske sprekker i frysen, vann tar mer plass i fast form enn i flytende form ... Vi gjør forsøk også prøver vi å finne en forklaring på det.

[t] Tom: Da er det jo det at det er jeg som gjør det ikke vel ... Forklare ting kanskje basert på elevenes observasjoner. Jeg kan jo ikke forvente at de skal forklare hvorfor eller hvordan det har blitt slik eller sånne ting, men det å forklare når en kan gjøre det, sette det inn, knytte det til noen vitenskapelige prinsipper eller begreper eller teorier som vi har ser jeg på som nyttig. Jeg vil de skal lære mest mulig om naturvitenskap så hvis jeg kan knytte det opp mot noe så gjør jeg jo det. Så ... Jeg liker å forklare ting, det er jo det undervisning er på en måte, formidling og forklare det på en måte som elevene skjønner det, om det er naturfag eller matte eller hva det er for noe så forklarer du jo så godt det lar seg gjøre. Forklaring så vel som observasjon er viktig tenker jeg.

[u]Victoria: Ja … kanskje ventet enda lenger på den forklaringsdelen egentlig, en er jo fort litt raskt ute ... Ofte blir det bare forsøk i starten av timen og forklaring på slutten. Kanskje en skulle ha venta enda litt lengre med forklaringen, bruke lengre tid på selve prosessen observasjon og beskrivelse ...
- Hvorfor tenker du det? Eller hvis du bare utdyper det?
Det er jo en større del av naturfaget også da, egentlig, selve prosessen ..., men det er mye læring i den også. Motivasjonen for å finne forklaringen … jo mer tid det går også, og hvor mer man får forsøkt det ... Forholdet man får til selve forsøket først, eller den observasjonen.

[v] Thomas: Jeg må bare tenke, for jeg må ofte tenke sånn, hva er ikke vitenskapelig fremgangsmåte ... Det er jo å si at du ser noe du som du ikke ser, det er iallfall noe av det ... Den naturvitenskapelig fremgangsmåte, da må du kunne nok til å se det du ser. Så gjelder det å øve seg på ikke å se noe som en ikke ser.

[w] Lisa: Jo det henger jo sammen. Men det er jo å fastholde den formen og funksjonen da, sånn som det med Aristoteles ... At … det er ikke alltid du vet hva du er ute etter heller fordi at du bare beskriver så kommer det til deg etter hvert. Sånn som de da, de visste jo ikke alltid hvilket dyr eller plante, eller at dyr hadde slektskap, det fant de jo ut etter hvert, med det de skrev da, og de har en hofte som er vokst sammen og et halebein som er der og ... Rudimentært organ som er der. De visste jo ikke det, de bare beskrev og beskrev og så sammenlignet de det, og så, ... åja, her var det noe likt.. Så vet ikke ...

[x] Elise: At dyr har mer farger og liksom ..., for en stein er bare grå og så bare en form, eller andre forskjellige farger, mens en sommerfugl har liksom forskjellige mønstre, forskjellig form og har liksom, det går liksom vinger og så er det en kropp der de henger fast. Det er mye mer på en sommerfugl eller en stein.

[y] Sebastian: Så det er jo gøyere å studere meitemark enn en stein.
Jeg: Fordi?
Sebastian: Det skjer mye mer med en meitemark enn en sånn stein.

[z] Meg: Hva tenker du er mest interessant da å studere?
Emma: Kanskje sommerfugler
Jeg: Ja. Fordi?
Emma: De har veldig mange detaljer

[æ] Emma: Den står helt stille hele tida, og den har veldig lite farger.
Jeg: Så det levende har ofte mer farger tenker du?
Emma: Ja

[ø] Peter: Det er mye enklere å tegne en stein siden den står helt stille, men en sommerfugl den kan liksom fly vekk, og så beveger sommerfuglen seg ganske ofte, den står liksom ikke stille når du skal tegne den. Og så er det mye mer med sommerfuglen en det er med en stein
Jeg: Hva er det som er mye mer tenker du?
Peter: Hva den spiser, det skjer jo mye med den siden den beveger seg og det er liksom noe med den siden den er levende.
Jeg: … og hva betyr at noe er levende tenker du?
Det betyr at det har følelser, og at det liksom ..., det er litt vanskelig å forklare

[å] Oliver: En stein er jo kanskje ganske mye verdt hvis det er en litt sånn …, for eksempel er et fossil, du har jo aldri sett dinosaurer, men det er bare sånne fossiler som er tegn på at de har levd, så ... (…) Det som jeg synes er litt rart det er at det koster jo mye mindre med sånn levende dyr enn fossiler, som liksom steiner, som liksom aldri har levd, det synes jeg er litt rart. (…) Steiner er jo bare harde, for eksempel. de der fossilene de er veldig harde, men de der dyrene de lever jo (…) Hvis det for eksempel er et fossil som noen har sett før så er det kanskje ikke så mye verdt, men hvis det er et fossil som ingen har sett før, som er for eksempel veldig lite eller veldig stort, så kan det koste ganske mye.
Meg: Ja, det er helt sant, og så synes du at det er litt rart at ikke de levende er mer verdt på en måte.
Oliver: Fordi de har jo allerede hatt et liv. Døde ting, det er jo liksom

[aa] Oliver: Jeg ser at det er liksom to sommerfugler med begge sidene på en måte, at en som viser bakdelen som er litt sånn svart og brun og litt sånn, og den fine sida som er liksom sånn dagpåfugløye, litt sånn som påfuglen, litt sånn farger, og så ser jeg en larve som holder på å nesten falle fra treet, og litt spisse blader, og to fluer, og en flue som lukter på et egg tror jeg, og en puppe som nesten blir sommerfugl, og en puppe som kanskje just har gått inn. Så ser jeg jo en Brennesle som alt det er oppe på.
Jeg: Hvorfor tror du hun har malt alt sammen sånn?
Oliver: Fordi hun skal vise en historie kanskje, ... en forvandling til at først egg og så larve kanskje, og så liksom puppe, utvokst puppe og sommerfugl da (…).

[bb] Jeg: Er det noe som er forskjell på det å observere en sommerfugl og en plante?
Sebastian: Ikke så mye egentlig synes jeg, fordi sommerfuglen har en slags sånn pollenbærer de også, eller som ligner veldig, som egentlig er følehornene, så de ligner ganske mye på en blomst. Er det ikke sånn at de også tar pollen og sprer det?
Jeg: Jo, de kan også gjøre det, så de henger litt sammen på en måte, er det litt sånn du tenker?
Sebastian: Ja, og så er veldig mye kamuflert, de kamuflerer seg på blomster synes jeg ...

[cc] Jeg: ... og en plante da, er den levende?
Emma: Den lever på en måte, men ... ja

[dd] Mia: Ja, de lever jo siden de har jo røtter som gjør at den kan leve tror jeg ...
Jeg: Ja ... For hvis du ser en plante, så tror jeg ikke du er i tvil om det er levende eller ikke, det er bare litt vanskelig å si hva som er forskjellen, er det sånn?
Mia: Ja, det er bare ... Siden et tre er jo levende!
Jeg: Ja, det er det. Kan du tenke deg hva det er som gjør at det er levende?
Jeg synes det ...at bladene spirer, eller at det blir til blader og sånn, at de skifter farge og sånn. Det synes jeg.

[ee] Mia: Sommerfugler er jo på en måte litt mer levende, men planter jo også veldig levende, jeg bare ... sommerfugler blir jo veldig sånn, først er de en ...et egg tror jeg, så blir de til en puppe, og så en larve og så en blir det til en sommerfugl, det er jo litt, det tar jo litt lenger tid på en måte, eller .... planter kan også ta lang tid på å gro opp, men det er ikke liksom like komplisert på en måte.
Jeg: Er det noe som er likt da?

Mia: Hmm ... At begge blir jo ... vokser og blir veldig fine egentlig, og får kanskje litt mønster og sånn.

[ff] Mia: Fordi det er liksom en spesiell lukt i naturen, man kan liksom bare føle det på en måte. […] Ja, jeg synes det godt å sitte i naturen egentlig
[gg] Jeg: Jeg har skrevet opp noe som jeg synes var litt fint, som du hadde skrevet, bladene føles litt som en klut. Kan du forklare hva du mente?
Peter: Det var litt sånne blader, litt sånn veldig, veldig, veldig sånn klut ... den var jo litt våt også. Da blir det liksom litt som en klut. […] Det var en sånn plante, det var en sånn grein, det var litt sånn vann på og så tok jeg på den, og så ...

[hh] Og så har jeg oppdaga veldig mange nye ting med sommerfugler, hvordan de ser ut og sånn. Siden når jeg ser en sommerfugl så tenker jeg liksom, ja den er gul --og rød, men så har jeg liksom sett at de ikke bare er det.

[ii]Sebastian: Altså, på dagpåfugløye er det viktig å få med at den er ganske rød på vingene og litt mer brun her nede på de to andre vingene, så har den på en måte øyne på vingene, og så er den litt sånn hvit rundt på ving ..., rundt øynene på en måte, og så foran har den litt sånn sebrastriper rett ved følehornene.

[jj] Jeg: Er det sånn at du liksom ...at det er annerledes det du ser og det som du får ned på papiret?
Sebastian: Ja! For blyanten går ikke helt det jeg har lyst til.
Jeg: Ja, det er ikke så lett, det er forskjell på det å se og det skulle få tegnet det?
Sebastian: Ja. Vi skulle en hai eller noen sånn en gang, da ville jeg så at det skulle bli en sånn finne på toppen, men det ble bare en klump, det var veldig irriterende

[kk] Jeg: Hvis du skulle sammenligne den og den f.eks., på hvilke måter er de like eller forskjellige?
Emma: De har litt like farger, så har de ikke helt lik form.
Jeg: Hva forskjellen på formen på vingene her?
Emma: Den er mer sånn ... den er mye lengre

[ll] Emma: Det var veldig gøy, men litt vanskelig også for man fikk ikke med alt.
Jeg: Ville du gjerne ha tegnet det enda nøyere
Emma: Ja
Jeg: Ja, men du liker å tegne eller
Emma: Ja
Jeg: Det kan jeg egentlig se at du gjør. ... Så hvis du skulle beskrive en sommerfugl for noen andre ville du synes det var bedre å tegne den enn å si det med ord f.eks..
Emma: Ja
Jeg: Så ville du gjerne fått lov til å bruke enda lengre tid og bruker farger og sånn også¨
Emma: Ja
Jeg: Så kunne du ha fargelagt alle de detaljene.
Emma: Ja

[mm] Sebastian: Få det røde her i midten, det er jo et kjennetegn, og det hornet foran. Og få kanskje det bak på kroppen her ...
Jeg: Hvordan synes du det var å lage en sånn larve?
Sebastian: Det var ganske gøy.

[nn] Jeg: Hva er det å være god til å observere da? Hva tenker du?
Peter: Å se de detaljene på en måte, se de beste detaljene ...
Jeg: Hva er det da? (…) Hva er det å se de beste detaljene?
Peter: Det er kanskje ... hvis f.eks. den der har liksom sånn små hår på seg, så du skisser sånn veldig små hår, hvis den liksom har f.eks. noe ... liksom forskjellig fra en annen en, så observerer du den veldig bra, hvis du f.eks., ser forskjell på to like arter som er på en måte forskjellig.

[oo] Jeg: Andre ting som gjør at man blir god til å observere, eller man må gjøre for å bli god?
Sebastian: Kanskje gå noen turer i skogen for å se etter noen småinsekt for å se om det er noe du bare kan se … om det er et nytt du ikke har sett før.

[pp] Mia: Det er kanskje litt enklere ute
Jeg: Fordi?
Mia: Fordi da kan man liksom se når den står oppe på en måte, står oppreist
Jeg: Ja, og hvorfor er det bedre?
Mia: Fordi da kan man se hvor man henter den fra og sånn, og det kan jo faktisk ..., det kan jo være fordel det

[qq] Elise: Hvis du er ute og ser på sånn virkelige planter, da får du mer med enn på et bilde, siden da kan du ikke snu på planten og se sånn nøye.

[rr] Jeg: Hva tenker du at man må gjøre for å bli god til å observere naturen?
Peter: Vet ikke ... være ganske stille
Jeg: Hva tenker du med det? Eller hvordan mener du?
Peter: Det er litt vanskelig hvis du skal få ting til å komme nærme deg, f.eks. en fugl, så du må sitte helt stille, hvis du bråker kan det hende du skremmer den vekk.

[ss] Jeg: Hvis læreren skal hjelpe dere med noe, hva tenker du at læreren kan hjelpe med?
Emma: Jeg vet ikke helt.
Jeg: Du er ikke helt sikker
Emma: Nei

[tt] Jeg: Hvis læreren skal hjelpe deg til å bli god til å observere naturen, hva kan læreren hjelpe med tenker du?
Emma: Å gjøre det mer på skolen
Jeg: ... og når dere skal observere på skolen, hva kan læreren ... skal læreren bare si observer de tre bildene, eller kan læreren gjør noe mer for å hjelpe dere til å bli gode?
Emma: Tegne det.
Jeg: Hvorfor det?
Emma: For da får man ... da tegner man detaljer og da ser man på en måte detaljene, hvis man tegner de detaljert.
Jeg: Ser man det bedre hvis man tegner, enn hvis man ikke tegner
Emma: Ja, tror det
Jeg: Hvorfor det tror du?
Emma: Fordi hvis man er nøye så kikker man nøye på hva man ser på bildet.

[uu] Sebastian: De må observere mye selv for å kunne vise oss hvordan vi skal gjøre det.
Jeg: Ja. Hvorfor det?
Sebastian: Fordi hvis de prøver å lære oss å observere og så ser ikke de alle detaljene, som vi burde ha sett, da mister jo vi noen av de detaljene vi burde ha sett

[vv] Jeg: Andre ting … hvordan læreren kan hjelpe?
Peter: Si hva du må se etter for --, for å se om det er en han eller hun så kan de si hvilken farge hannen har og si hvilken farge hunnen har, så finner du at av hvilken type eller om det er en han eller hun, eller hvilken fugl det er, om den har spisst eller skarpt nebb eller hva den gjør.

[ww] Oliver: Hun observerte de veldig mye, hvis hun fant en f.eks.. en ny larve så tok hun den med hjem og så hadde hun den der og matet den og stelte den og alt sånn, og så venta hun til å se hva som skjedde med den., og så ble de fleste ..., alle dyrene hun hadde fanga, de hadde liksom hatt sånn der egg, så hadde de blitt larver, så hadde de blitt puppe og så hadde de blitt sommerfugl, og så hadde hun lagd over femti sånne observasjoner, og så skrev hun ned hva som skjedde hver dag.
Jeg: […] På hvilken måte var hun vitenskapskvinne eller forsker?

Oliver: Kanskje for at hun var den første biologen, som uten utdanning da, bare greide å finne ut av det.

[xx] Han [Linné] tok å pressa de [plantene] tror jeg, og så la han det i sånn hyller som han kunne flytte på, og så tok han sikkert noen sånne ark og limte han de på ark og sånn og så la han de i hyller, og så skrev han sikkert sånne lapper der det stod navnene på de greiene, og så brukte han kanskje sånne bokser som han la de

[yy] At han [Linné] likte å få system på ting, han ville ikke ha det så rotete, siden da var det vanskelig å finne frem til hva han skulle ha.

[zz] Jeg: Det har dere jo også snakket litt om i timen, hva betyr det å være systematisk?
Emma: Eeehm ... å på en måte sortere det, eller f.eks. hvis man har masse frø i en boks, så kunne man heller hatt det i mindre bokser, og ha de like frøene i en boks.

[ææ] At f.eks. du har en sånn hylle med skuffer, så setter du de blåe blomstene i en skuff, og så rød og så gul, og så etter når du har gjort det da blir det et slags system, for da får du hatt alt under kontroll. […] Da blir det lettere å observere, lettere å holde styr på.

[øø] Ja, fordi i England er det sikkert ikke så mye sånn tropiske dyr som det er rundt i Amazonas og alle de regnskogene, de var der for å se hvordan dyr så ut der, så fikk de liksom et annet syn av hvordan dyr egentlig var.

[åå] Jeg: Hvordan var det de kom frem til en sånn forklaring, hva var det de gjorde?
Sebastian: Husker iallfall at de sendte brev til hverandre og så ... de hadde jo ... ja, han der ... tror det var D, han hadde jo drivhus i hagen og gjorde mange eksperimenter og sånn

[aaa] Jeg: Hva vil det si da å øve på det observere?
Thomas: Det er godt spørsmål, men bare for å tenke høyt ..., så tenker jeg det har ..., på samme måte som du øver på andre ting, skal en god til å sykle så må en sykle, og skal en bli god til å observere, så må man observere. … ja.
Jeg: Men er det noe mer enn bare å si observer eller ...?
Thomas: Nei, men en må øve seg i å sette ord på ting, på samme måte som noen har det mer medfødt enn andre når det gjelder alle slags egenskaper, så er det noen som har lettere for å sette ord på ting og ... ---, jeg tror jeg hadde måttet øve på å sette ord på ting og kommunisere de til andre

[bbb] Hvis en skal øve på.. Det er vel å gjøre det mange ganger da og at man ..når de er 10-11 at det får en konkret ting de skal observere når de først--- og gjør de bevisst på å bruke sansene og hvilke sanser man bruker og, være litt konkret i starten da. Eehm...ja.. og at man bruker observasjonene til noe i etterkant.

[ccc] Det jo den tilstedeværelsen og fokus, altså at elevene har fokus og vi har fokus på det vi gjør, og ikke gjøre alt mulig annet. Så det må være å fokusere.

[ddd] Nei, det er jo skape situasjoner hvor en har fokus på ulike objekter da, eller deler av objekter, og på en måte ha tid ikke minst, og ro, sånn at de omliggende faktorene skal også være på plass for på en måte kunne få det fokuset som skal til da.

[eee] ... da blir det å gjennom observasjonsoppgaver at du får beskjed om å observere et eller annet, om du enten da gjør det retta, at du skal se etter noe spesielt, eller om du gjør det uretta eller hva du skal kalle det, men en oppgave der de øver på å skrive ned observasjoner, så går vi gjennom de litte granne, hvilke ord kan vi bruke som passer inn hvis vi skal beskrive mønsteret på insekter så må de ha noe ordforråd å putte på ... hva var spørsmålet igjen?
- Hva det vil si å øve på det å observere?
Og så gjør man sånn og så stiller man reflekterende spørsmål til eleven sånn at den også ser andre ting, eller ser det fra en ny vinkel, hva med dette, eller hva med ..har den noen svingekøller insektet eller et eller annet sånn, så legger de merke til det.Vet ikke, jeg tror det er å øve på å observere.

[fff] Tom: Jeg tror folk blir overrasket over hvor stort biologisk mangfold man egentlig har rundt seg, jeg tror ikke folk kikker ned i gresset, de ser bare gress der, men hvis vi ser er det jo forskjellige typer gress, det er også andre planter innimellom, du ser en sopp og insekter, så en har ganske stort biologisk mangfold innenfor et ganske lite område hvis en bare ser etter, men jeg tror folk ikke observerer naturen, de bare går forbi den rett og slett. Jeg bare la merke til min egen hage når jeg ikke gadd å luke der hvor stort biologisk mangfold jeg hadde av ulike ugress som dukket opp, så ja ...

[ggg] Jeg: Hvilken betydning mener du at observasjon kan ha i læringen om biologisk mangfold?
Thomas: Nei, jeg tror jo på akkurat samme måte som det kan være funksjon i læringen av alle andre ting, veldig pedagogisk fordi det du observerer, har sett, det du har kjent, det du har lukta, det du har sagt, husker man bedre enn ting som du bare har fått inn gjennom ørene. ... ja, og så var det jo som en begynte med at naturen er jo ikke så nærme oss i 2020 som den var for de som vokste opp for hundre år siden, og to hundre år siden, og antageligvis vil den kanskje ikke komme noe nærmere heller hvis ikke man bevisst oppsøker den tenker jeg.

[hhh] Lisa: Jeg synes jo kanskje, hvis jeg skal skryte litt av meg selv, men jeg synes det med de sommerfuglene var best fordi du så at de fikk frem så utrolig mange detaljer, spesielt når de malte på sommerfuglen. Hvis vi skal liksom vurdere, det der vurdering for læring og se hva de har fått med seg, så var det noen som hadde fått med seg utrolig mye, og når de da kunne skape om til sitt eget, så var det mange detaljer der, med de eggene under, og hvilke type blad og ..., noen var på tistelen og ja..tistelsommerfuglen. Jeg synes kanskje det var kanskje det beste. Så er jo sommerfugler også veldig takknemlig ting å jobbe med ...
Jeg: Fordi?
Lisa: Fordi de er liksom så vakre, det fenger de med disse fargene og ... Planter er jo også fengende, men kanskje ikke så mye. Jeg vet ikke.

[iii] Victoria: Så er det jo veldig fargerikt da, siden vi snakket om farger i stad, det er jo ..., jeg tror det setter seg litt bedre, de jo veldig fargerike de sommerfuglene ...
Jeg: Andre ting du tenker med de sommerfuglene som er spesielt, som fenger elevene på en måte?
Victoria: Jeg tror jo alle var jo litt kjent med de far før av da, sommerfuglenes livssyklus, så de hadde nok litt av ..., ja litt utgangspunkt, de følte nok det var litt kjent for de i starten også. Så det tror jeg spilte inn. Men jeg husker ... jeg la merke til når vi skulle begynne på noe nytt, såp husket de veldig mye om Merian, hvor hun bodde og trykkeriet til stefaren og, så jeg tror det har festet seg historien om Merian også.

[jjj] Jeg: Kanskje kunne man levd ser mer inn i hvordan det var på den tida og sånn?
Tom: Jeg følte vi kom litt inn på det når svi snakket om lukta og sånn på det trykkeriet..
Jeg: Ja, nettopp. I det heftet var jeg bevisst, så spilte jeg ekstra mye på det med det sanselige, fordi det var en del hennes tilnærming
Tom: Ja, jeg tror det funket bra, det tror jeg..

[kkk] Tom: (…) det var jo Lisa sin ide med de skoeskene og det her. Det er noe ikke jeg hadde sett for meg i mitt hode hvordan kom til å se ut, hunprøvde å forklare det til meg, og jeg bare sier, jeg stoler på det at dette blir bra, men jeg ser ikke helt hvordan du skal gjøre det. Og da kan jeg bare stole på henne og så blir det et bra resultat på en måte. Det er jo i det prosjektet som vi alle jobber med, så alle bidrar med sin bit, så blir det bedre enn hvis en skulle ha gjort det alene. Skulle jeg ha gjort det elene, hadde det blitt veldig Tom-formet hele greie, kanskje enklere, kanskje mer firkanta, kanskje mer sånn dette er jeg trygg på, mens nå har vi liksom mer sånn litt av hvert og andre innspill og andre metoder og ...

[lll] Lisa: Det er jo egentlig først og fremst overføring av kunnskap, men det er jo så mye mer, fordi undervisningen er for meg det er på en måte å lære de å være mennesker.

[mmm] John: Nei, en kan ikke gi det ..., du kan ikke fylle på kunnskap i hodene til disse, men vi kan tilrettelegge for prosesser, og så er det jo hvordan vi klarer å tilrettelegge det på en god måte, og da er jeg veldig opptatt av å prøve å gjøre ting praktisk, de må ..., det gjelder jo i alle fag, konkretisere så mye som mulig.

Jeg: Og hvorfor det?
John: Fordi jeg tror det er veldig mange som tilegner seg da lærdommen, kunnskapen, kompetansen, ... altså det blir, det sitter mer ..., når hele kroppen har fått på en måte har fått prøvd.

[nnn]Tom: Det er jo en form for formidling, du formidler informasjon til elevene som du vil at de skal forstå. Informasjonen kan enten være kunnskap eller det kan være metoder sånn som i matte, hvordan de skal gjøre ting, eller i naturfag også får vi metode. Men det handler om å skaffe elevene lærdom ...ja ...om de temaene som vi har bestemt vi synes er viktige at de skal kunne noe om... Det er en formidling! Formidle kunnskap, det som sitter i mitt hode skal inn i elevenes hode, så gjelder det å finne riktig metode for å nå inn. (…) Det er en konstant prosess og det er vanskelig.

[ooo] Tom: Du vil ha de til å se det samme som du ser, liksom observere det du observerer når de observere et gitt fenomen eller en gitt ting da

[ppp] Tom: Både det vi har gjort her med observasjon som metode og litt av hvert sånn, men også ting som jeg har gjort i Nysgjerrigper, med at de stiller sine egne spørsmål og finner sine egne svar, og lærer å lære som det står i den nye læreplanen, det har alltid vært viktig, særlig i naturfag, for det er ikke et skrivefag, ikke et leksefag som norsk, matte og engelsk, men det er likevel et viktig fag fordi man skal lære naturfagsferdigheter der, vitenskapeferdigheter, skepsis og alt det gode ... Sunn fornuft.
[qqq] Victoria: Jeg sjøl da har hatt mest fokus på hvorfor, men så tenker jeg hva- spørsmål er jo like viktig og det kommer litt mer med i de nye læreplanene dette med fokus på hva, da ligger det jo hva man ser, observasjon og beskrivelser og ... ja, mer fokus på selve prosessen da.
[rrr] Tom: For min del når jeg var nyutdannet var jeg mer redd for å være like utforskende og sånn der ting, for det at det er trygt å ha konkrete måle som elevene testes etter, det er vanskelig å måle hvor rasjonell har du blitt i dag eller hvor kritisk tenkende har du blitt i dag eller sånne ting, hvor utforskende er du, det er lettere å gå på en prøve og se han husker det, det, det fakta, og da er det lettere og kanskje tryggere og legge opp undervisningen der du har noe å teste det på... se her! de har lært det de skal lære. Men så etter hvert ... når jeg har blitt litt mer varm i trøya, så har jeg fått mer mot kanskje til å gjøre det liksom på min måte, sånn som jeg vil at det skal være, det er jo sånn jeg har skjønt at det skal være også, de vil ha det.. på den utforskende lære måten, på den måten. Men ... det har blitt lettere etter hvert og kunne gjøre det sånn.
[sss] Jeg: Hvis du skulle tolke det selv, hva tenker du at de utsagnet sier?
Thomas: Det sier vel at en må lære å observere ... og at enkelte tinge ligger mer naturlig for mennesker å observere, blant annet sine egne artsfrender. Det er mer sånn ..for moderne mennesker så er det jo helst mennesker man treffer, bygninger og situasjoner i trafikken man ser, så hvis en skal trekke det videre til naturen da, så hadde en jo observert naturen på en annerledes måte hvis en hadde levd i den på en måte.

[ttt] Vi som lærere skal gi elevene kunnskap, men det også viktig at vi ikke bare «lesser dem med masse kunnskap», det er viktig at elevene selv får utforske og lære ting på denne måten. Kanskje vi også kan lære noe av elevenes perspektiver på ting?

Appendices

Appendix A

Log template

Du skal skrive en logg knyttet til hver undervisningsøkt som er merket med navn, dato og sted. Med logg mener jeg en nedtegnelse av hendelser, erfaringer og refleksjoner. Loggen er i hovedsak en tekst, men du kan gjerne laste opp bilder, tegninger eller notater for å illustrere eller dokumentere det du skriver.

Tenk gjennom den undervisningsøkten du har vært med på. I hver logg vil jeg at du

- gir en kort beskrivelse av økten
- beskriver hva du lærte og hvilke spørsmål som eventuelt dukket opp underveis som du ønsker å undersøke nærmere
- uttrykker dine tanker om hvordan du eventuelt kan bruke dette i egen undervisning
- setter ord på eventuelle andre tanker, assosiasjoner eller ideer

Muntlig sier jeg:

> *En logg trenger ikke å være så strukturert, den kan være litt fragmentert og ikke nødvendigvis helt gjennomtenkt, du trenger ikke å pusse på fine formuleringer, skrivingen skal være mer utforskende og til støtte for skriverens egen tankeutvikling. Du vil få sjansen til å utdype og kommentere det du har skrevet i intervjuet.*

Appendix B

Course evaluation template

1. Observasjon (5 min) – bilde 1

Du kan velge om du vil vektlegge estetiske aspekter, holistiske aspekter (fokusere på helheten) og/eller mer sammenlignende, analytiske, systematiske eller forklarende aspekter i observasjonen:

- Hva ser du?
- Hvilke assosiasjoner får du?

2. Observasjon (5 min) – bilde 2

Du kan velge om du vil vektlegge estetiske aspekter, holistiske aspekter og/eller mer analytiske, systematiske eller forklarende aspekter i observasjonen;

- Hva ser du?
- Hvilke assosiasjoner får du?

3. Hva mener du er *felles* for de 5 personene som er fremstilt i de fire historiske «casene» som har blitt presentert (eks. personlige egenskaper, omgivelser)? Hva vil du si er vesentlige *forskjeller* dem imellom?

4. Hva vil du si kjennetegner de 5 personenes måter å observere på, både likheter og forskjeller?

5. I kurset har vi gjennomført følgende praktiske øvelser som har handlet om ulike måter å observere på:

a. tegnet og beskrevet detaljer ved meitemarken
b. laget terrarium for munkelus og meitemark
c. sammenlignet ordener av insekter (foto)
d. studert spesifikke trekk ved et utvalgt insekt (preparat) – beskrevet med ord og tegning, brukt oppslagsverk
e. sett på kjennetegn ved ulike løvtrær ute i nærområdet
f. sammenlignet sanseinntrykk (syn, hørsel, lukt) i ulike typer av skog i nærområdet
g. samlet inn og systematisert blomster og blader fra løvtrær i nærområdet
h. beskrevet en utvalgt sommerfugl (preparat) i ulike stadier sammen med vertsplanten
i. beskrevet en utvalgt plantefamilie med utgangspunkt i bestemte deler av blomst og frukt, og samtidig studert et -to planteeksemplarer som representerer plantefamilien

Hvilke/n vitenskapelig/e måte/r å observere på mener du at vi har øvet i disse øvelsene?

1. Hvordan mener du at praktiske øvelser og elevenes egne erfaringer med det å observere planter og dyr på ulike måter (som de over) kan tilrettelegge for elevenes læring?

2. Hvordan mener du en historisk kontekst rundt naturvitenskaplige spørsmål og måter å observere på kan tilrettelegge for elevenes læring?

3. Noe du ønsker å tilføye? (kommentarer, spørsmål og assosiasjoner)

Appendix C

Interview guide for the first interview with teachers

Tema	**Spørsmål**	**Individuelle spørsmål**
Min bakgrunn og bakgrunn for forskningen	*Utgangspunkt for prosjektet har vært å finne hvilke framgangsmåter som historisk sett har vært fruktbare for å kunne klassifisere og få kunnskap om biologisk mangfold. Og med tanke på undervisning; hvilke ferdigheter som er sentrale i denne sammenhengen og hvordan kan vi øve disse i skolen.*	
Lærerens bakgrunn (utdannelse, erfaring og undervisningsfag)	Hvordan ble du lærer? (Hva er viktig for deg som lærer?) Hva kjennetegner din undervisning? (Hva kjennetegner din måte å øve elevenes ferdigheter på)?	
Lærerens refleksjon over egen læring og egen undervisningspraksis knyttet til ferdigheter og utforskning av biologisk mangfold	Hvordan har du opplevd dette kurset? Hva sitter du igjen med som det mest sentrale? Vi har arbeidet med ulike ferdigheter i forbindelse med det å observere naturen. Hvilke ferdigheter sitter du igjen med som verdifulle for deg som lærer? Hvordan vil du øve disse sammen med dine elever? I. Aristoteles var blant annet opptatt av å skille mellom ren observasjon og forklaringer. a. Hvilken betydning mener du at ren observasjon kan ha i læringen om biologisk mangfold (planter og dyr)? b. Hvis du tenker tilbake på din egen tid som lærer, er det undervisningsopplegg hvor du har arbeidet med ren observasjon? c. Hvis ikke, eller hvis du skulle gjennomføre det på nytt, hvordan ville du gjøre det da? II. Merian var opptatt av å beskrive organismene i en sammenheng og uttrykte seg på en estetisk måte. a. Hvilken betydning mener du at det å arbeide med å beskrive organismene kan ha i læringen om biologisk mangfold (planter og dyr)? b. Hvis du tenker tilbake på din egen tid som lærer, er det et undervisningsopplegg hvor du har arbeidet med å beskrive? c. Hvis ikke, eller hvis du skulle gjennomføre det på nytt, hvordan ville du gjøre det da? III. Linne var opptatt av å systematisere observasjonene av ulike arter a. Hvilken betydning mener du at det å arbeide med å systematisere observasjoner kan ha i læringen om biologisk mangfold (planter og dyr)? b. Hvis du tenker tilbake på din egen tid som lærer, er det et undervisningsopplegg hvor du har arbeidet med å systematisere observasjoner? c. Hvis ikke, eller hvis du skulle gjennomføre det på nytt, hvordan ville du gjøre det da?	

	I. Wallace og Darwin var opptatt av å forklare observasjonene de og andre hadde gjort. a. Hvilken betydning mener du at det å forklare observasjoner av organismene kan ha i læringen om biologisk mangfold (planter og dyr)? b. Hvis du tenker tilbake på din egen tid som lærer, er det undervisningsopplegg hvor du har arbeidet med å forklare observasjoner? c. Hvis ikke, eller hvis du skulle gjennomføre det på nytt, hvordan ville du gjøre det da? Sammenfatning av c): Hvis du skulle ha arbeidet med disse ferdighetene med dine elever på nytt, hvordan ville du gjøre det?	
Lærerens refleksjon over egen læring og egen undervisningspraksis knyttet til det å lære om et tema i en historisk kontekst	Hva sitter du igjen med etter å ha arbeidet med temaet biologisk mangfold i en historisk kontekst? a) Hvilken betydning har den historiske konteksten har hatt for din forståelse av naturvitenskapen som prosess? b) Hvilken betydning mener du det narrative elementet ved en fremstilling av tema i en historisk kontekst kan ha i læringen? c) Har du brukt en historisk fremstilling av et tema i din egen undervisning? Hvordan? d) Hvis du skulle ha tatt dette i bruk i din egen undervisning, hvordan kunne du tenke deg å gjøre det?	
Lærerens refleksjon over egen læring og egen undervisningspraksis knyttet til det å lære om naturvitenskapelige fremgangsmåter	a) Hva mener du er en naturvitenskapelig/-e fremgangsmåte/ -r? b) Hvis du tenker tilbake på din egen tid som lærer, er det et bestemt undervisningsopplegg hvor du har arbeidet med dette? c) Hvis ikke, eller hvis du skulle gjennomføre det på nytt, hvordan ville du gjøre det da? *Eventuelt:* - *Betydningen av flere perspektiv* - *Spenningen mellom det sanselige og det objektive* - *Forholdet mellom hva og hvorfor i undervisningen*	
Artsbegrepet	- *Hva er en art?* - *Hvordan mener du Aristoteles, Merian, Linne og Darwin oppfattet en art? Hva var likt og hva var grunnleggende forskjellig?*	
Avslutning	Noe mer du ønsker å tilføye? Hva tenker du om spørsmålene du fikk?	
Åpent tema (til notater og spørsmål som dukker opp underveis)		

Appendix D
Observation guide for observations in the classroom

Observasjonsguide
Jeg skal observere lærerens (undervisnings) **praksis** knyttet til fenomenet **observasjon**. Observasjonen klasserommet skal bidra til en mer helhetlig forståelse av denne praksisen og da er det kanskje mest interessant å legge vekt på det som ikke nødvendigvis sies i et intervju, når jeg observerer.

Lærer:	**Rom/ sted:**	Dato:
Ulike dimensjoner ved lærerens praksis knyttet til fenomenet observasjon		
Sted og materialer - klasserommet	**Kroppslig praksis** - hvordan lærerens praksis kommer til syne på ikke-verbale måter	**Diskurs** - forholder lærerens praksis seg til en bestemt forståelse av *hva naturvitenskap er*
f.eks. hvordan klasserommet og det som finnes der setter begrensinger/ gir muligheter for lærerens praksis og elevenes observasjon.	*f.eks. om læreren viser/demonstrerer hvordan elevene skal observere, peker på hva som er viktig, gir ikke-verbal respons på hva som er riktig/ ikke riktig…*	*f.eks. hvilke rolle det å observere og beskrive spiller i forhold til det å forklare i lærerens forståelse, hvordan vises dette i praksis?*
Dokumentasjon av elevarbeider – tegninger, tekst, samtale…		

Appendix E

Interview guide for the second interview with teachers

Tema	**Spørsmål**	**Individuelle spørsmål**
	Du har nå lest gjennom transkriptet av intervjuet vi gjorde i juni 2019. Hva sitter du igjen med? Er det noe du har lyst til å utdype eller si noe mer om? Jeg har plukket ut et av dine utsagn, hvis du skulle tolke det, hva tenker du at dette utsagnet sier? …..	
	Hva er dine erfaringer med gjennomføringen av undervisningen knyttet til dette prosjektet sist skoleår og denne høsten?	
Theme 2: To know what to look for, or not? To practice the skill of observation	Dere har gjennom prosjektet fått erfaring med ulike måter å observere dyr og planter sammen med elevene. Hva er det å observere tenker du? Hva vil det si å øve på det å observere? • *Hvilken betydning mener du at observasjon kan ha i læringen om biologisk mangfold (planter og dyr)?* • *Hvilken betydning mener du at det å arbeide med å beskrive organismene kan ha i læringen om biologisk mangfold (planter og dyr)* • *Hvilken betydning mener du at det å arbeide med å systematisere observasjoner kan ha i læringen om biologisk mangfold (planter og dyr)?* • *Hvilken betydning mener du at det å forklare observasjoner av organismene kan ha i læringen om biologisk mangfold (planter og dyr)?*	
Theme 3: Leading or walking along? The role of the teacher in observation.	Hva innebærer det å undervise for deg? (Hva er for deg god undervisning? Hva legger du særlig vekt på i din undervisning?)	
Theme 1: What are the things we observe? The nature of living nature	I dette prosjektet har tema vært biologisk mangfold, eller vi kunne ha sagt den levende delen av naturen. Hva kjennetegner den levende naturen for deg? Hva er en art?	
Theme 4: Observation as part of a scientific process	Hva mener du er en naturvitenskapelig/-e fremgangsmåte/ -r? Hvordan inngår observasjon som en del av en naturvitenskapelig fremgangsmåte tenker du?	
Avslutning		
Åpent tema (til notater og spørsmål som dukker opp underveis)	Andre ting som påvirker gjennomføringen av slikt prosjekt? Team Organisering	

Appendix F

Interview guide for the interview with students after working with the case of Linne´

Intervjuguide elever – Uke 25 – Etter å ha arbeidet med heftet om Linne og hatt uteundervisning om planter.

På bordet ligger noen planter elevene har arbeidet med, i tillegg har de med heftet om Linne hvor de har svart på oppgaver og feltboka hvor de har skrevet opp egne observasjoner.

Related themes		**Spørsmål**
Theme 4: - Do students express connections between observing and being a scientist? How?	Elevens umiddelbare uttrykk for erfaringer	Når har dere lært om Linne og øvd dere på å observere planter. Har du fortalt noen hjemme noe om hva dere har gjort? Hva har du fortalt? / Hva ville du har fortalt? I timen har dere snakket litt om det å være systematisk – hvordan var Linne systematisk?
Theme 2: - Do students observe in different ways? What and how?	Elevens observasjon	Her er noen planter som jeg har plukket. Kjenner du igjen noen av dem? Kan du fortelle hva du ser?
		Hvordan vil du sortere plantene? Er det noen som hører mer sammen enn andre? Hvorfor?
Theme 2: - How do students express their observations in different ways?	Elevens arbeid med egne beskrivelser og uttrykk	I timen tok jeg noen bilder når dere jobbet med … / observerte ute ... Kan du fortelle meg hva dere gjorde her?
		I timen la jeg merke til noe du sa … / Her har du skrevet … / På tegningen her ser jeg at du har tegnet … Kan du fortelle meg mer om det?
Theme 3: - How do students see the role of the teacher		Synes du det er vanskelig å observere planter? Hva synes du er vanskelig? Hvordan kan læreren best hjelpe deg tenker du?
Theme 1: - How do students respond to the living?	Elevens oppdagelser	Har oppdaget noe nytt når du har observert og tegnet planter?
		Er det noe du har lyst til å finne ut mer om?
		Dere har observert meitemark, insekter, sommerfugler og planter. Er det noen forskjell på det å observere en sommerfugl og en plante? Er det noe som er likt? (*Når vi sier at noe er levende. Hva betyr det?)*