Science education for our common future: Education for sustainable development in science teacher education

Naturfagsundervisning for vår felles fremtid: utdanning for bærekraftig utvikling i naturfagslærerutdanning

Philosophiae Doctor (PhD) Thesis

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Forord

Da var doktorgradsarbeidet snart ved veis ende og 'the never ending story' ser ut til å ha en slutt allikevel. Det har vært en lang reise, men samtidig har den brakt meg langt. Jeg har lært veldig mye og truffet mange hyggelige mennesker på min vei. Disse har bidratt på ulike måter og fortjener alle en takk.

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Summary

The aim of this thesis was to develop knowledge on how education for sustainable development (ESD) can be realised in the education of science teachers. The aim was pursued through three articles: one theoretical article addressing how secondary school chemistry education can be an arena for ESD and two empirical articles investigating the realisation of ESD in the science teacher education program at the Norwegian University of Life Sciences (NMBU). The science teacher education program at NMBU has the overall aim of educating teachers who can contribute to sustainable development, making the institution a valuable case to study.

In the first article, a model of how ESD can be realised in chemistry education was developed. The model consists of five categories: chemical content knowledge, chemistry in context, the distinctiveness and methodological character of chemistry, ESD competencies and lived ESD. Through the model, we aimed to support chemistry teachers in their educational planning and the model visualises how ESD can be realised in chemistry education, even when sustainability is not specifically taught as content.

In the second article, we investigated how ESD can be realised in science teacher education. The article reports from the case study at NMBU and provides an example of how ESD can be realised through a strengths approach where ESD is founded in the strengths among the teacher educators and existing teaching practices. The results indicate that an emphasis on sociocultural learning theory and experiential learning builds a thorough foundation for ESD. The sociocultural learning theories contributed to the social aspect of ESD through the university culture of the teacher education institution that mirrors the school culture of a sustainable school, with a particular focus on collaboration and the learning environment. Furthermore, through a focus on experiential learning, teaching approaches such as context-based teaching, outdoor education, phenomenon-based teaching and inquiry learning were included, enhancing the emphasis on pupil participation and science in context. However, the teaching has to be explicit in order to reach all student teachers.

The third article explores the realisation of ESD in a residential field course arranged at the beginning of the academic year for the NMBU teacher education program. It, thus, provides a more in-depth exploration of one part of the teacher education program discussed in Article II. Through the residential field course, the student teachers gained experience in outdoor education, experience in spotting subject issues in nature and they gained inspiration and

ideas from each other. The teaching included active learning approaches, such as inquiry learning and phenomenon-based teaching. Inquiry learning showed a potential of realising all categories of the ESD model, and particularly ESD competencies. Furthermore, phenomenon-based teaching contributed with connecting the sciences to an everyday context and allowing the learners to be affected by the environment. The residential field course also provided the student teachers with experience of stepping into something unknown, which is an important exercise in preparing for ESD, since ESD requires teachers who are willing to explore content knowledge without fixed answers and the inclusion of pupil-centred teaching approaches.

Sammendrag

Målet med dette studiet har vært *å utvikle kunnskap om hvordan utdanning for bærekraftig utvikling (UBU) kan realiseres i utdanning av lærere til naturfagene (naturfag, kjemi, biologi og fysikk)*. Dette har resultert i denne avhandlingen som inkluderer en teoretisk artikkel om hvordan kjemiundervisningen kan være en arena for UBU, samt to empiriske artikler som tar utgangspunkt i en undersøkelse av UBU-tilnærmingen ved naturfagslærerutdanningen på Norges miljø- og biovitenskapelige universitet (NMBU). NMBU har satt som et overordnet mål for lærerutdanningsprogrammet at de ønsker å utdanne lærere som kan bidra til bærekraftig utvikling, noe som har gjort denne casen spesielt interessant.

I avhandlingens første artikkel presenterer vi en modell for hvordan UBU kan realiseres i kjemiundervisning. Modellen består av fem kategorier: fagkunnskap, kontekstbasert kjemi, fagets egenart og metodologiske karakter, UBU-kompetanser og levd UBU. Gjennom modellen søker vi å støtte kjemilærere i undervisningsplanlegging rettet mot UBU, og vi eksemplifiserer hvordan UBU kan være en naturlig del av kjemiundervisningen, også når det faglige temaet ikke er knyttet til problemstillinger om bærekraftig utvikling.

I den andre artikkelen undersøker vi hvordan UBU kan realiseres i utdanningen av naturfagslærere. Artikkelen bygger på studiet fra NMBU og gir et eksempel på hvordan UBU kan realiseres i et lærerutdanningsprogram ved å bygge på eksisterende undervisning og kompetansen som lærerutdannerne innehar. Funnene fra studien indikerer at sosiokulturell- og erfaringsbasert læringsteori utgjør et godt fundament for UBU. Den sosiokulturelle læringsteorien bidrar til det sosiale aspektet i UBU, gjennom en universitetskultur ved lærerutdanningsprogrammet som speiler en bærekraftig skolekultur med et hovedfokus på samarbeid og et godt læringsmiljø. Videre bidrar erfaringsbaserte undervisningsmetoder som kontekstbasert undervisning, uteundervisning, fenomenbasert undervisning og utforskende arbeidsmåter til et spesielt fokus på elevmedvirkning og undervisning som elevene kan oppfatte som relevant. Samtidig indikerer studien at undervisningen må være eksplisitt nok for at lærerstudentene skal kunne avdekke hensikten med undervisningen.

I den tredje og siste artikkelen undersøker vi hvordan UBU er realisert på en ekskursjon i lærerutdanningsprogrammet ved NMBU. På denne måten bidrar artikkelen med en mer grundig utforskning av en av samlingene fra artikkel 2. Gjennom ekskursjonen fikk studentene erfaring i uteundervisning og i å oppdage undervisningsressurser i naturen. De fikk også inspirasjon og ideer fra hverandre ved å undervise hverandre i grupper, samt at

mange opplevde å måtte utfordre seg selv knyttet til oppgavene som ble gitt. Gjennom øvelser på feltkurset fikk studentene erfare utforskende arbeidsmåter og fenomenbasert undervisning. Analysene viste at utforskende arbeidsmåter bidro til alle de fem kategoriene i UBU-modellen, og spesielt UBU-kompetanser. Videre bidro fenomenbasert undervisning til å knytte fagene til konteksten og til at studentene ble berørt av omgivelsene. Erfaringen studentene fikk av å utfordre seg selv kan anses som nyttig ettersom UBU krever lærere som både tør og er villige til å utforske usikker kunnskap og undervisningsmetoder der elevene er i førersetet.

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CSCT	Curriculum, Sustainable development, Competences, Teacher training)
EE	Environmental education
ENSI	Environment and School Initiatives
ESD	Education for sustainable development
GAP	Global Action Programme
LUR	A five-year teacher education program
NMBU	Norwegian University of Life Sciences
NOS	Nature of science
PPU	A one-year post-graduate teacher education program
SLL	Section for teaching and teacher education
UN	United Nations
UNECE	United Nations Economic Commission for Europe

PART I:

EXTENDED ABSTRACT

1 Introduction

This thesis is written within the fields of education for sustainable development (ESD) and science education. Today's changing world faces severe global challenges; the sustainability of the planet is threatened and the problems are expected to accelerate as human pressure on the Earth's environmental systems continues to increase (United Nations, 2015a; United Nations Environment Programme, 2012). Thus, new demands are put on today's youth, as they will play a major role in the Earth's future development. The challenges are more complex and multifaceted than before, and the present and coming generations need new kinds of competencies in order to act differently from previous generations.

Alongside these societal changes, the development of knowledge societies also increases the demands on and challenges for schools, as the educational systems are preparing young people for jobs that do not yet exist (Voogt & Roblin, 2012). The aims and content of science education have been subject to a long debate concerning the relevance of science education (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013) and there has been a shift in the purpose of science education, from preparing future scientists, towards the education of future citizens (Aikenhead, Orpwood, & Fensham, 2011; Orion, 2007; Osborne & Dillon, 2008; Roberts, 2011). Despite a shift in how we look at science education, there is still some way to go with respect to changes in the actual teaching, which, to a large extent, still focuses on the education of future scientists (Osborne & Dillon, 2008; Stuckey et al., 2013).

In Norway, a committee was appointed by the Norwegian government to assess the competency requirements needed in future social and work environments, and to discuss how the common core subjects in primary and secondary education (i.e. the Norwegian language, mathematics, natural science, English, social science and physical education) must change accordingly. In their report (Ministry of Education and Research, 2015), the committee pointed to the challenges society and its individuals were facing with respect to development and they called for an update of the school subjects due to the schools' vital role in society:

> Today's and tomorrow's society has and will have new requirements when it comes to participating in a number of settings like work, organizations, home and leisure. Individuals and society also face local and global challenges relating to social, cultural, economic and technological development, and to how we can ensure sustainable development. School as a communal arena is gaining greater importance than was previously the case. . . . School must support but also influence the values and norms that are the foundation of society. School must help to develop pupils'

> potential as individuals. . . . If the potentials of pupils are to be realised, the subjects must be renewed and school must be developed. This is how new conditions for pupils' learning can be created and how competences for the future may be developed. (Ministry of Education and Research, 2015, pp. 7-8)

As a part of the process of renewing the core subjects, the committee pointed to sustainable development as one of three topics that will be especially important in the future and therefore should have a vital role in the new curricula.[1] The Ministry of Education and Research followed up with Report No. 28 to the Norwegian Parliament stating that 'Sustainable development shall be a prioritised topic in the [revised] curricula. Education in this interdisciplinary topic shall, in line with the objects' clause, contribute so that the pupils learn how to think critically and act ethically and environmentally' (Ministry of Education and Research, 2016b, p. 39, my translation).

ESD has been in focus during the last two decades, especially after the United Nations (UN) General Assembly adopted resolution 57/254 (United Nations, 2002) to put in place a UN Decade of Education for Sustainable Development (hereafter addressed as *the Decade*), beginning on January 1st 2005. The aim of the Decade was to change the approach to education so that it integrates the principles, values and practices of sustainable development (UNESCO, 2005c). The Decade has passed and the UN is now continuing to pursue ESD through the Global Action Programme (GAP). The GAP follows up on the work done during the Decade, with an enhanced focus on the generation of concrete actions (UNESCO, 2016a).

In the current strategic plan for ESD in Norway, which applies to kindergartens, primary education, secondary education and teacher education programs, the stated vision is that 'Norway should have an educational system that contributes to sustainable development locally and globally' (Ministry of Education and Research, 2012, p. 5, my translation). The strategic plan points to the possibilities of realising ESD in a Norwegian context and the significance of teacher education is also argued for:

> The way education for sustainable development is included in the [curricula] provides possibilities, but places large demands on the schools' and teachers' organisation and facilitation of education. Thus, the necessity of concentrating on the enhancement of

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[1] The other two topics were 'public health and life management' and 'the multicultural society' (the latter was changed to 'democracy and citizenship' in Report No. 28 to the Norwegian Parliament).

> competency [for ESD] among teachers, student teachers and teacher educators is emphasised. (Ministry of Education and Research, 2012, p. 16, my translation)

In other words, the necessity of developing this competency among teachers is clear and the teacher education institutions need to contribute to this matter. One teacher education institution which has taken this challenge seriously is the teacher education institution at the Norwegian University of Life Sciences (NMBU).

In the Section for Learning and Teacher Education (SLL) at NMBU, there is an overall goal for the department, which states that it wants to educate teachers who can contribute to sustainable development (NMBU, 2009). In an external evaluation of the teacher education programs at the university,[2] it was concluded that although ESD was evident in the teacher education programs, the student teachers still did not perceive ESD as holistically realised (Dolin, Linløkken, Tonheim, & Bildeng, 2012). Therefore, the evaluation committee recommended developing science education for sustainable development and a model for ESD related to the extensive international literature and practice in the area, adapted to the Norwegian culture and the traditions of the university.

In my PhD project, I have been following the process of reorienting the teacher education programs towards the overall aim. The empirical work was carried out in science education, but when following the recommendations from the evaluation committee and developing a model for ESD, I chose to develop a model for chemistry education. This is mainly because I have my educational background in chemistry, but also because analyses of the curricula, which I will return to in Section 3.1, showed a clear need for a model for chemistry. Besides, the development of the model was more concise when it was restricted to one scientific subject. Since chemistry education is a part of science education and therefore has many of the same characteristics, I used the same model in the analysis of the science education program – a choice I will discuss in Sections 2.3.3 and 4.4.5.

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[2] One study program at the university is evaluated each year, and in 2012, the teacher education programs were subject to evaluation.

1.1 Aims and research questions

Recognising the importance and opportunities of ESD and the need for science ESD both locally and internationally, the main aim of this thesis is *to develop knowledge on how ESD can be realised in the education of science teachers*. There are different views on how to best educate for sustainable development and there are no specific guidelines on how it should be done, since the teaching approaches and topics differ according to local contexts and priorities (UNESCO, 2005c, 2012). My emphasis is on teacher education, but I believe that one cannot say how a teacher can realise ESD without starting out with the pupils' learning in mind. I therefore started from the pupils and what they needed to learn in order to consider what the student teachers needed to learn. Hence, the starting point of the thesis is a model for how chemistry education can be an arena for ESD. This is further elaborated into science teacher education through a case study at NMBU, investigating the realisation of ESD in the teacher education program.

The following research questions are addressed in the articles:

A. How can secondary school chemistry education be an arena for ESD?
B. How can ESD be realised in science teacher education?
C. How does an ESD-oriented science teacher education program realise different approaches to ESD through a residential field course?

The first two research questions are quite open. This is a deliberate choice because my intention is to investigate the possibilities latent in ESD and thereby develop knowledge according to the aim of the thesis. Due to the comprehensive research questions in the articles, no overarching research question is formulated for the thesis. I will instead use the extended abstract to further investigate the research questions and through these questions suggest how teacher education programs can facilitate for their student teachers to be competent in realising ESD in their future teaching.

1.2 My entrance into and understanding of the field

I have always been a hard-core science and mathematics person. In primary school, mathematics was my favourite subject and I calculated literally all of the maths assignments that my primary school had to offer. When I started upper-secondary school, a specialisation in mathematics, chemistry and physics was a natural choice, and I loved it.

I am also a social person, and ever since my mathematics teacher in grade 4 taught me how I could best assist my fellow pupils in learning mathematics, I wanted to become a teacher. Great teachers during my secondary school years strengthened that desire, and when I started at NMBU in 2003, it was with the aim of becoming a teacher. Alongside my studies, I worked as a substitute teacher at a local upper-secondary school and also as a teaching assistant on some of the chemistry courses at the university. My parents' farm was open to visitors and I also worked teaching children and families about animals and agriculture. All these experiences increased my desire to become a teacher. However, the teacher education program also introduced me to educational research, a field I find very interesting, and that guided me into doing this PhD.

Doing a PhD on the topic of ESD has been challenging in several ways, especially due to different understandings of the concepts of sustainability and ESD, which I will elaborate on in Section 2.1. Burmeister and Eilks (2013) investigated German student teachers' understanding of sustainability. They found that most student teachers associated the term with an ecological context such as environmental problems, pollution, exhaustion of resources, climate change and renewable energy. No similar studies have been conducted in Norway, but according to the current national strategy for ESD in Norway, the emphasis in the educational system has been on the environmental dimension of ESD and not on the global development dimensions (Ministry of Education and Research, 2012). It is therefore plausible that Norwegian student teachers have similar associations regarding sustainability and, consequently, a limited understanding of ESD.

Straume (2016) compared the approaches to sustainability taken in Norway and Sweden, and pointed to a difference in the countries' cultures: 'Where the Norwegian nature- and environment protection traditions have had an identity-forming role, with roots in the grass roots movements and nationalism, the Swedish national identity has been more connected to the modern society and less to national romanticism' (Straume, 2016, p. 90, my translation). This is in line with my experience of the understanding of sustainability in Norway and can be illustrated by a conversation I recently had with an elderly colleague of mine. When I told her my thesis was about ESD, her first response was: 'so you are politically active?' Thus, the understanding of ESD for several Norwegians still seems to be situated in the environmental dimension, and sometimes with a political connotation.

In my work, it has been important for me to present views of ESD that exceed an environmental focus and with an emphasis on critical thinking and capacity building. I will elaborate on this perspective in Chapter 2. It has also been important for me to emphasise an optimistic view of the future. In an empirical study investigating 51 Norwegian science teachers' realisation of ESD, Sundstrøm (2016) found that most teachers expressed a pessimistic view of the future. This can be considered problematic, because to put it in the words of Noam Chomsky (as cited in e.g. Gault, 2009, p. 9), 'unless you believe that the future can be better, it's unlikely that you will step up and take responsibility for making it so'.

This optimistic view is what I find to be at the core of my PhD with respect to ESD realisation; I aim to search for possibilities rather than challenges. Based on my experiences from teaching in schools, it has also been important for me to introduce perspectives on ESD that are applicable to schools. I have therefore founded my work on an 'education through science' perspective, where educational skills are acquired through scientific subjects (Holbrook & Rannikmae, 2007). Thus, the teachers may still follow the curricula and their demands, but the ESD perspective is taken care of through the choice of context and working methods.

Finally, with a background in chemistry, it has been important for me to include chemistry education as a part of the thesis. But again, from my perspective, ESD in chemistry is much more than environmental chemistry, and this is a view that colours the thesis.

1.3 Clarifications

In this section, I will clarify the use of the concepts *science education* and *outdoor education*, and the relationship between *science education* and *chemistry education* in the thesis. Clarification of the ESD concept is put off until Section 2.1, where it is thoroughly discussed.

The teacher education program at NMBU is divided into modules focusing on either didactics or pedagogy. Didactics in this respect links theory and praxis and the definition of didactics followed in the teacher education program is 'practical-theoretical planning, conduction, assessment and critical analysis of teaching and learning' (Hiim & Hippe, 2006, p. 16, my translation). The word *didactic* is, however, perceived differently around the world. In Scandinavia and the continental part of Europe, there is a wide understanding of the term including the process of selection and organisation of content and the selection of forms and teaching methods (Gundem, 2000). In other parts of the world, the word is considered negative and moralising. According to Hamilton (1999, p. 135) '[i]t denotes formalist educational practices that combine "dogma" with "dullness". . . . It conjures up the unwelcome European ghosts of an unattractive educational past'. In order to avoid the wrong interpretation of the word, I have chosen to use *science education* instead of *didactics*.

The term *outdoor education* also has different meanings according to geographical location. In the Anglo-Saxon tradition, the term is often connected to adventurous experiences focused on e.g. team-building, whereas in the Scandinavian tradition it usually involves school-based learning outside the classroom (Fägerstam, 2014). Outdoor education can take place in several arenas not only limited to nature environments. Potential arenas for outdoor education include museums, science centres, farms, laboratories, etc. (Frøyland, 2010; Tal, 2012). All these arenas may contribute to a more relevant and context-based teaching, giving the learners opportunities to learn about reality in real environments. However, when talking about outdoor education in this thesis, I am focusing on nature as an arena for teaching and learning.

The thesis is positioned within *science education* with a particular focus on *chemistry education*. The empirical work was done in science education, due to the small numbers of chemistry student teachers attending the teacher education program each year. The number of student teachers in physics is even smaller, and the teacher education program therefore keeps all student teachers in science education in one group. There are a few sessions throughout the year devoted to the specific scientific disciplines, but the groups are merged for most sessions. In the extended abstract, literature from science education and chemistry education is used intertwined, since chemistry education is a part of science education. This is, to some extent, unproblematic, since chemistry education is a part of science education and therefore has many similar characteristics, but you still miss out the role of technology in society, which is a part of the nature of chemistry, but not a part of the nature of science (NOS) – as discussed in Article I.

1.4 Outline of the thesis

The thesis consists of an extended abstract and three articles. The extended abstract aims to justify the theoretical and empirical choices I have made in my PhD project and explains the background and contribution of the three articles presented. This is done through six chapters: *introduction*, *review of relevant research and policies*, *the empirical context*, *methodology*, *summary of the papers* and *discussion.*

Following this introduction, I will present a literature review of relevant research on ESD. This chapter also includes a presentation of the development of the field of ESD and reflection on the ESD terminology. In Chapter 3, I will place the research into an empirical context, starting broadly from the Norwegian context and narrowing it down via the university to the teacher education program. I have further devoted Chapter 4 to a discussion of the methodology used in the thesis, and summaries of the three articles are given in Chapter 5. Finally, Chapter 6 provides a discussion of the articles.

The three articles follow the discussion and are briefly described on the next page. The first article was published in 2015, while the second article was accepted in 2017 and will be published in 2018. The third article was published in 2017.

The relationship between the articles is illustrated in Figure 1. Article I addresses how ESD can be realised in chemistry education overall and thereby has the broadest perspective. In Article II, we explored the realisation of ESD in the science teacher education program at NMBU through the analytical framework developed in Article I. Finally, in Article III, the realisation of ESD in one specific module in the teacher education program at NMBU (i.e. from Article II) was explored using the categories from the framework developed in Article I.

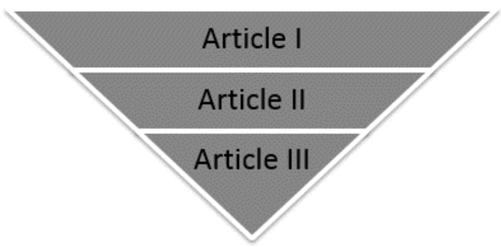

Figure 1: Illustration of the relationship between the three articles

Jegstad, K. M. & Sinnes, A. T. (2015). Chemistry teaching for the future – A model for secondary chemistry education for sustainable development. International Journal of Science Education, 37(4), 655-683

The first article presents a model for chemistry ESD. The model aims to develop sustainable chemistry education within the current chemistry curriculum.

Jegstad, K. M., Sinnes, A. T. & Gjøtterud, S. M. (in press). Science teacher education for sustainable development: From intensions to realisation. NorDiNa

In the second article, we explored how ESD was realised in the teacher education program studied. The article provides an example of how ESD can be realised in science teacher education programs through a strengths approach (also called a strengths model) where the education is founded in the strengths among the educational labour force.

Jegstad, K. M., Gjøtterud, S. M. & Sinnes, A. T. (2017). Science teacher education for sustainable development: A case study of a residential field course in a Norwegian pre-service teacher education program. Journal of Adventure Education and Outdoor Learning

Whereas the second article looked at ESD in the teacher education institution overall, the third article explored the residential field course arranged in the beginning of the academic year in depth. The aim of the paper was to explore how the residential field course can contribute to ESD in a pre-service teacher education program.

2 Review of relevant research and policies

In this chapter, I will lay the theoretical foundation for the articles of the thesis through an overview of sustainable development and ESD. This includes a presentation of the background and history of ESD, together with the ESD debate. ESD is described in both the research literature and policies, and this part of the review will therefore be related to both types of documents. Moreover, I will focus on research concerning ESD in science education and teacher education. Finally, I will point to the limitation of the existing research and what can be gained from empirical studies of ESD in teacher education programs. This part of the chapter will also include a presentation of the ESD model developed as a part of the thesis, and this model is discussed in relation to the literature review and other relevant ESD models.

2.1 An overview of literature about sustainable development and ESD

The research literature operates with different understandings of what sustainable development is (Dobson, 1996), and what ESD is and can be (de Haan, 2010; Fien & Tilbury, 2002; S. Gough & Scott, 2006; Huckle, 1996; Orr, 1992). I will start this section with a discussion of the concept of sustainable development. I will thereafter reflect on the ESD terminology.

2.1.1 The concept of sustainable development

The term *sustainable development* arose originally from professions such as forestry and fishery, discussing issues such as how many trees could be cut or how many fish could be taken, and still have respectively forest growth and functioning fishery at the end of a certain time period (Rogers, Jalal, & Boyd, 2008). The term was reintroduced in 1987 by the World Commission on Environment and Development, also known as the Brundtland Commission in their report *Our Common Future* (World Commision on Environment and Development, 1987), and it implied meeting the needs of the present generation without compromising the ability of future generations to meet their needs. In *Our Common Future*, the Brundtland Commission called for changes in human attitudes that 'depend on a vast campaign of education, debate, and public participation' (World Commision on Environment and Development, 1987, p. 23). UNESCO (2005b, p. 2) later followed up with a definition of sustainable development as

> a vision of development that encompasses populations, animal and plant species, ecosystems, natural resources – water, air, energy – and that integrates concerns such

> as the fight against poverty, gender equality, human rights, education for all, health, human security, intercultural dialogue, etc.

There are several tensions within the sustainability debate. Scott and Gough (2003) listed a set of tensions and paradoxes related to sustainable development by juxtaposing: change versus continuity; empowerment versus prescription; 'me' versus 'we'; present generations versus future generations; humans versus nature; local versus global; and rich versus poor and very poor. The tension between human versus nature can further be related to the debate about *ecocentric* and *anthropocentric* worldviews. In an ecocentric perspective, the environmental concern is directed towards other species or ecosystems. In an anthropocentric perspective, humans are seen as separated from nature and more worthy than other species; the individuals care about environmental protection because of environmental threats, either directed towards them and their families (i.e. self-interested individuals) or a larger community (i.e. human altruistic individuals) (Kopnina, 2014).

An anthropocentric worldview is nothing new, and can be traced back to early times, as illustrated by the Biblical quotation:

> Then God said, 'Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea and the birds in the sky, over the livestock and all the wild animals, and over all the creatures that move along the ground.' (Genesis 1:26 New International Version)

Another well-known tension in the sustainability debate is between sustainable economic growth and sustainable human development. The emphasis on sustainable economic growth is linked to the current social and economic system, and aims for a more sustainable path of economic development, while the emphasis on sustainable human development is questioning the present worldview of unlimited economic growth and therefore calls for radical changes in the social and economic system (Fien & Tilbury, 2002). An often used approach to sustainable development, which addresses this tension is a focus on the three dimensions in Figure 2. Sustainability demands an emphasis on the *environmental* dimension in order to stop climate change and loss of biodiversity. The *economic* dimension is important to decrease the difference between rich and poor, assess personal and societal levels of consumption, and evaluate limits and potential of economic growth linked to the two other dimensions. Finally, the *social* dimension is connected to human rights, democracy, and individuals and their attitudes, behaviour and relations (Sandås & Isnes, 2015; UNESCO, 2016b). All three dimensions must be emphasised in sustainable development and they should be considered from local, regional and global points of view (Burmeister, Rauch, & Eilks, 2012; de Haan, 2006). Politics and culture are also important dimensions and considered to influence the interactions of and between the other three dimensions (UNESCO, 2016b). Some also include health or wellness as a fourth category (Vaughter, McKenzie, Lidstone, & Wright, 2016).

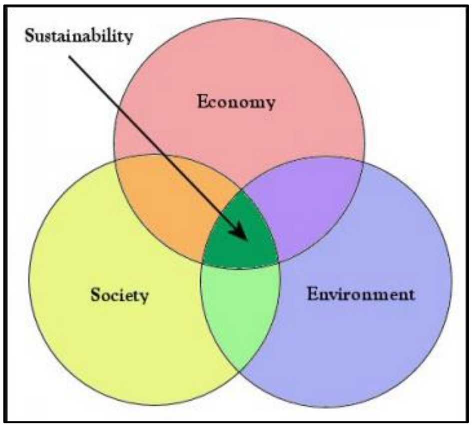

Figure 2: The three dimensions of sustainable development (Koppelman, 2013)

The benefit of the model in Figure 2 is that it illustrates how environmental issues are interwoven with social and economic considerations. A critic of this model is, however, that actors could be satisfied by addressing any one of the categories – and not all three of them together (Vaughter et al., 2016). McKenzie, Bieler, and McNeil (2015) therefore suggested to introduce the categories as a 'nested concept' with environment in the outer circle and economy in the inner circle, emphasising the interrelationship of the categories: '[t]hey are placed in this hierarchy based on the understanding that without a natural environment human beings would not exist, and without a society to create it, there would be no economy' (p. 329).

Sustainability has been on the political agenda for the past decades through UN conferences and reports (Dag Hammarskjöld Library, 2017). The first environmental conference was held in Stockholm in 1972, and the focus was on preservation and enhancement of the human environment (United Nations, 1972). Several agreements have resulted from these conferences, with the Montreal Protocol[3] (United Nations, 1987), Agenda 21[4] (United Nations, 1992), and the Kyoto Protocol[5] (United Nations, 1998) as major achievements.

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[3] Adopted in 1987, aiming to eliminate the use of ozone depleting substances
[4] One of the resulting documents of the Earth Summit, hosted in Rio de Janeiro in 1992, describing the wide public participation needed to create sustainable development (United Nations, 1992)
[5] Adopted in 1997 introducing legally binding emission reduction targets for developed countries in the time period 2005 to 2020

Part I: Extended Abstract

In 2000, the Millennium Development Goals were established following the Millennium Summit of the UN. This meeting was the largest gathering of world leaders in history (as of the year 2000), and all UN member states agreed on eight development goals, which have functioned as the overarching development framework for the world for the following 15 years (United Nations, 2015b). The eight millennium development goals were: (1) eradicate extreme poverty and hunger; (2) achieve universal primary education; (3) promote gender equality and empower women; (4) reduce child mortality; (5) improve maternal health; (6) combat HIV/AIDS, malaria and other diseases; (7) ensure environmental sustainability; and (8) develop a global partnership for development. Although great achievements have been made, the progress has been uneven (United Nations, 2015c). Thus, several new challenges to achieve sustainable development have been identified: gender inequality; big gaps between the poorest and richest households, and between rural and urban areas; climate change and environmental degradation, where poor people suffer the most; conflicts as a big threat to human development; and millions of poor people still live in poverty and hunger, without access to basic services (United Nations, 2015b).

As a response to these challenges, the 2030 Agenda for Sustainable Development was launched in September 2015. The 2030 Agenda builds on the Millennium Development Goals and seeks to complete what these goals did not achieve. In addition, while the Millennium Development Goals were targeted on the developing countries, the new sustainable development goals include all countries, also the more developed nations. The 17 aims with a total of 169 targets listed in Figure 3 attempt to balance the three dimensions of sustainable development. The aims came into effect on January 1st 2016 and shall guide the decisions taken by state leaders over the next 15 years.

Figure 3: The 2030 Agenda for Sustainable Development (United Nations, 2015b)

Goal 4 in the 2030 Agenda is about education, and focuses on ensuring 'inclusive and quality education and promote lifelong learning opportunities for all' (United Nations, 2015c, p. 14). Further, the following aim for ESD is stated in target 4-7:

> By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development (United Nations, 2015c, p. 17).

Another big milestone also occurred in 2015: the world's countries did not only adopt the new sustainable development agenda, but also a new global agreement on climate change, i.e. the Paris Climate Agreement (United Nations, 2015a). The Paris Climate Agreement requires that both developed and developing countries take action, and not only the developed countries, which was the case in the Kyoto Protocol (United Nations, 1998).

In the next section, I will move from sustainable development to ESD, and provide a discussion of the ESD terminology, both with respect to environmental education (EE) and with respect to the term in itself.

2.1.2 The ESD terminology

ESD was first described in Chapter 36 of Agenda 21, and the role of education in being critical 'for promoting sustainable development and improving the capacity of the people to address environment and development issues' was stressed (United Nations, 1992, p. 320). Even though Agenda 21 stated that education is critical for promoting sustainable development, Sterling (1996) has claimed that education both is a part of the problem and of the solution: 'education is proclaimed at high level as the key to a more sustainable society, and yet it plays a part in reproducing an unsustainable society' (p.18). This quote emphasises the importance of the second thrust of Agenda 21: the existing education needs to be reoriented to address sustainable development (United Nations, 1992).

There are different opinions of what ESD *is* and, whether it *can* and *should* be defined (Jickling, 1992). Different understandings of ESD can, for one, be related to the concept of identity and diversity among human beings, because individuals' worldview and belief systems affect their perception (Dillon, 2013). Human encounters and interactions have been recognised as central in understanding sustainability issues (Lundegård & Wickman, 2009), since identity is developed when people meet. Hence, when individuals develop meaning, the view of the current situation is coloured by prior experiences (Dewey, 1938), and different understandings of ESD are therefore inevitable, both among educators and learners.

Breiting (2007) complicates the matter by asking whether sustainable development is at the core of ESD. There is, according to Breiting, no simple relationship between the terms because we do not know what sustainable development is. He concludes 'that for the students' own development it is much more stimulating that they by themselves develop a concept of what they regard as "sustainable development" than they exercise alternative existing definitions of sustainable development' (p. 21). It is easier to identify what is unsustainable than what is sustainable, and Wals (2007) therefore emphasised that 'sustainability as a social learning *process* is more interesting than sustainability as an expert predetermined transferable *product*' (p. 18, original emphasis). Thus, the concept of *social learning*, which refers to 'learning that takes place when divergent interests, norms, values and constructions of reality meet in an environment that is conducive to learning' is emphasised (Wals & van der Leij, 2007, p. 18). Wals (2007) argues that social learning is important to create a reflexive society that can respond to emerging challenges, and this is at the core of sustainability.

Sterling (2012) argues that ESD in essence ‘is about the kinds of education, teaching and learning that appear to be required if we are concerned about ensuring social, economic and ecological well-being, now and into the future’ (p. 8) and he further emphasises how ESD ‘prepares people to cope with, manage and shape social, economic and ecological conditions characterised by change, uncertainty, risk and complexity’ (p. 9). This is in line with our emphasis in the articles, focusing on preparing the younger generation to become *responsible citizens* (Burmeister et al., 2012) and developing ‘the knowledge, values and skills to participate in decisions about the way we do things individually and collectively, both globally and locally, that will improve the quality of life now and without damaging the planet for the future’ (Summers, Childs, & Corney, 2005, p. 629).

Huckle and Wals (2015) analysed literature supporting the Decade and concluded that it was ‘business as usual’ since the facilitators failed ‘to face up current global realities’ due to ‘inadequate guidance, misplaced idealism or the censoring of more critical ideas and content’ (p. 492). They also pointed to factors including lack of attention to power, politics and citizenships, and alternative forms of social and environmental relations. Vare and Scott (2007) also criticised the view of ESD underlying the Decade and other formal education initiatives, since it tended to emphasise expert-driven knowledge, with the role of the non-expert being to respond according to the given knowledge. The authors found this worrying since we become less sustainable if we are not allowed to think critically and feel empowered to take responsibility.

There are several debates related to the ESD terminology as well. A common debate among ESD scholars is whether EE equals ESD (McKeown & Hopkins, 2003, 2007). In an online discussion,[6] which considered the relationship between ESD and EE, four perspectives were found prevalent among the participants: EE as a part of ESD, ESD as a part of EE, ESD and EE as overlapping concepts, and ESD as a stage in the evolution of EE (Hesselink, van Kempen, & Wals, 2000). The latter was most common among the experts, and is also the view I hold on the relationship between ESD and EE, which is the reason why I lean on

[6] International Union for Conservation of Nature and Natural Resources Commission on Education and Communication published the results of a discussion between 50 invited experts from 25 different countries.

literature from both fields when developing arguments in ESD. Founded in this perspective, ESD came out of EE, which again has its roots in nature conservation education.

Nature conservation education arose from a concern that natural areas were disappearing due to urbanisation. The education was therefore primarily oriented towards basic resources, a better understanding of the natural world and protection of the carrying capacity (A. Gough, 2013; Wals, Tassone, Hampson, & Reams, 2015). Later, EE arose due to an evolving environmental crisis and concerns about pollution and accumulation of toxins. Thus, in the shift from nature conservation education to EE, the focus was 'less on understanding, appreciating and connecting nature, but rather on educating citizens in becoming environmentally responsible in their behaviour' (Wals et al., 2015, p. 26). Many scholars in the early EE movement thought that EE had '*a* methodology, *a* system, *a* conceptual framework [and] *a* set of goals' (A. Gough, 2013, p. 16, original emphasis). EE was, in other words, considered to be something specific that could be implemented in the school system through science education and the incorporation of ecological concepts. Following the Brundtland report (World Commision on Environment and Development, 1987), the emphasis broadened to include a full range of academic disciplines, and activities were developed to support the linkage between lifelong learning and sustainable development (Scott & Gough, 2003).

According to A. Gough (2013), ESD contributed to enhanced relevance of EE and many researchers have therefore changed their focus from EE to ESD. Within this enhanced relevance, there was a shift from individual knowledge about ecology in EE to a general approach to teaching and learning in society in ESD (Sund, 2008). In a review from a biologist's point of view, Smyth (1995) presented his visions of the shift from EE to ESD. These included: a less problem-oriented vision of the future; the inclusion of social and human development issues such as responsibility and citizenship, in addition to environmental concerns; and more emphasis on understanding, affective learning, wise choices and effective actions, rather than pure knowledge. Kopnina (2012) expressed concern about this anthropocentric shift. However, even though the anthropocentric and ecocentric perspectives differ, Kronlid and Öhman (2013) stressed that they are not synonymous with, respectively, a non-environmental-friendly and an environmental-friendly perspective. The objection to anthropocentrism held by the ecocentrists is that nature should also be valued independent of human needs; thus, according to the ecocentrists, the anthropocentric perspective is half right (Cocks & Simpson, 2015).

The term ESD is also contested in itself. One aspect is the notion of *development*, and this is often at the heart of the debate (Summers, Corney, & Childs, 2003). Development is a complex matter, and the word can be considered negative, related to the discussion about 'sustainable economic growth' versus 'sustainable human development' (Fien & Tilbury, 2002); sustainable development is often understood to imply continual growth, which again would increase the demands on the resources (Filho, 2000). However, from the perspective of developing countries, development is an essential aspect and sustainability cannot be achieved in these countries without continued development (Dresner, 2002). Some scholars have chosen to solve the dilemma of *development* by using education for sustainability instead of ESD.

Other scholars use sustainability education instead of ESD, in order to avoid the use of the preposition *for*. Education should teach the learners how to think, rather than what to think, because 'the whole notion of authoritatively prescribing how people should live their lives is fundamentally undemocratic and, therefore, unsustainable' (Wals, 2010, p. 147). Thus, education *for* something is inconsistent with this criterion (Jickling, 1992; Jickling & Wals, 2013). The concept of democracy is extensively used in the ESD literature, and learners are supposed to be allowed to develop values and opinions in a democratic way (Östman, 2010). However, through the use of the preposition *for*, a particular educational and value-based outcome is expected, which makes the education instrumental and ESD potentially normative and non-democratic with a danger of indoctrination (Jickling, 2003; Shephard & Brown, 2017; Östman, 2010).

Despite the contestedness of the term ESD, it is the terminology used most often at the international level and in United Nations documents (Hopkins & McKeown, 2002); ESD is, therefore, the term I use in this thesis, agreeing with McKeown, Hopkins, Rizzi, and Chrystalbridge (2002) who thinks about *for* as indicating a purpose.

2.2 ESD at two levels

The focus so far has been mainly on the ESD terminology and I have clarified some fundamental aspects related to the term. In this section, I will look into different perspectives of ESD from the research literature, with a particular focus on science education and teacher education.

Within the ESD literature, many scholars differentiate between education *about* sustainable development and education *for* sustainable development (e.g.Gadotti, 2008; McKeown et al., 2002; Palmer, 1998). Education *about* sustainable development includes a theoretical discussion about the topic of sustainable development, while education *for* sustainable development refers to how education can be used as a tool to build a more sustainable future (Gadotti, 2008; McKeown et al., 2002). Other scholars also include a third group: education *in* sustainable development, which is linked to creating enhanced understanding and emotional connections through experiential learning and interactive learning processes in an environment (Juntunen & Aksela, 2014; Kopnina, 2014).

Sterling (2003) has a similar division when describing three possible responses of the educational system to sustainability. He describes education *about* sustainability as a kind of accommodation or 'cosmetic reform', where new elements are add-on to the existing curricula, pedagogy and other aspects of the educational system. Education *for* sustainability is further described as a reformation, where new elements are built in to the current system through critical reflection. The third step is education *as* sustainability, which includes transformation of the system, and rethinking current practice. 'The shift here is towards "learning as change" which engages the whole person and the whole learning community, whereby the meaning of sustainable living is continually explored and negotiated through – as far as possible – living it' (p.286).

This division between education *about*, *for*, *in* and *about* sustainable development will be used throughout this thesis to systemise the ESD initiatives and is further discussed in Section 2.3.2 and Chapter 6.

2.2.1 Science education for sustainable development

In science education, ESD is often centred on education *about* sustainable development through known geo-bio-physical phenomena and processes such as climate change, water scarcity, land degradation, depletion of fish stocks, biodiversity loss and deforestation (Jerneck et al., 2011). Research has warned that this traditional, science-oriented approach to ESD, emphasising theoretical knowledge about environmental issues and descriptions of increasingly worsening conditions, can lead to a feeling of disempowerment among pupils (Jensen & Schnack, 1997). Nagel (2005) labelled the feeling of disempowerment 'learned hopelessness' and stressed the need for teaching to induce courage, commitment and desire to solve problems. Summers and Child (2007) also warned that a factual presentation of the science of sustainability issues may lead to misrepresentation of NOS, and that pupils may perceive the scientific knowledge as *certain* knowledge.

Education *for* sustainable development, on the other hand, includes more than knowledge about the environment, economy and society – it also includes attitudes, values and perspectives that guide pupils to live more sustainable lives (Gadotti, 2008, 2010). Gadotti (2008) juxtaposed ESD with education for another possible world:

> Educating for another possible world is to give rise to what does not yet exists, to utopia, to the 'possible not yet seen' (Paulo Freire). Educating for another possible world is to make spaces in education for training critical minds rather than for training only a workforce for the market. It incents new spaces for complementary training and denies the hierarchical form of formal systems that gives orders and promotes subordination. (p. 26)

This is in line with Wals (2011), who stressed the focus on capacity building and critical thinking for the learners to be able to understand what is going on in society and determine what needs to be done. This may also facilitate an ability to include imminent or future problems of which we are not necessarily aware of yet (Jerneck et al., 2011), because what appears sustainable today may turn out to be unsustainable later – or in other contexts (Wals, 2010).

In 2000, an evaluation of the realisation of environmental and sustainability education in Swedish schools was performed. An important outcome of this evaluation was the identification of three different teaching traditions in teaching about environmental and sustainability issues. These were *fact-based, normative* and *pluralistic* environmental education (Rudsberg & Öhman, 2010; Öhman, 2007).

In the *fact-based tradition*, environmental issues were seen as knowledge problems. In line with education *about* sustainable development, the belief was that science can solve all problems; thus the issues had to be dealt with by more research and by providing more information to the public (Rudsberg & Öhman, 2010; Sandell, Öhman, & Östman, 2003). In the *normative tradition*, the task of education was 'to support an environmental friendly transformation of society. . . . [S]chools are thus obliged to teach students the necessary environmentally friendly values and attitudes and, in this way, support changing students' behaviours in the desired direction' (Rudsberg & Öhman, 2010, p. 97). In the *pluralistic tradition*, different perspectives, views and values were acknowledged and there was a broadening of the topic to include the whole spectrum of social development in addition to environmental education. Hence, by replacing the environmental concept with the sustainability concept and including economic and social perspectives, the pluralistic tradition has simply been juxtaposed with ESD (Öhman, 2006).

An important aim of ESD is to prepare the pupils to participate in debates and decisions on sustainability issues (Öhman, 2008). The pluralistic teaching emphasises democracy in particular, since the aim is to enhance the pupil's competence to act and participate in the democracy in a conscious way; it takes the democratic role of education at the same time as indoctrination is avoided. According to Borg, Gericke, Höglund, and Bergman (2012, p. 188), '[s]tudents should be encouraged to evaluate different perspectives actively and critically, and it is important, in contrast to the normative tradition, not to impose values and attitudes on the students'. However, ESD is not just a matter of preparing for democracy, but also ensuring that pupils can experience democracy (Sandell et al., 2003), as worded by Laumann (2007, p. 23):

> If we take the children by the hand to 'help' and 'control' them, the children will only have the options we know and will only be able to repeat the mistakes we have made. Instead, we should create a learning space for children to act as entrepreneurs, capable of imagining new ideas and better solutions.

Thus, in order to '*create a future'* rather than 'cope in an *already defined future'*, ESD should invite pupils to participate according to their own ideas and experiences (Juntunen & Aksela, 2014, p. 492, orginial emphasis). Exposure to different perspectives is also important to ensure rational decision making (Tan & Pedretti, 2010).

Even though the pluralistic teaching tradition has been suggested as the most prominent way to teach, studies indicate that it is not properly followed up. The fact-based and the normative teaching traditions were developed during the 1970s and the 1980s, respectively – but are still in force in many Swedish classrooms (Rudsberg & Öhman, 2010). This correlates with an interview-study we did with teachers two years after they attended the teacher education program (Sinnes & Jegstad, 2011). Both our interviewees emphasised education *about* sustainable development rather than education *for* sustainable development, and were in the fact-based tradition – in agreement with the emphasis on education *about* sustainable development found in the Norwegian curricula (The Norwegian Centre for Science Education, 2010).[7]

Another possible explanation is the challenge that lies in the fact that 'teachers themselves are product of a system they are supposed to change', as pointed to by Letschert (2004, p. 12); teachers and student teachers tend to draw on their preconceptions about teaching, and construct their own professional knowledge, understanding and identity through reflecting on their own experiences (Day, Kington, Stobart, & Sammons, 2006). This explanation is in line with another Swedish study, where Borg et al. (2012) found that teachers from different subjects perceived ESD differently, which in turn created consequences for the way they incorporated it into their teaching. The science teachers tended to lean towards the fact-based tradition, believing that if pupils received the correct scientific facts, they would automatically take the right actions regarding environmental issues. Their teaching was therefore usually teacher-centred with elements of laboratory work, excursions, field-trips and study visits (Borg et al., 2012). There is, in other words, a specific need and challenge for science teacher education programs in addressing ESD. In the next section, I will discuss research related to ESD in teacher education, starting out from higher education in general.

2.2.2 Teacher education for sustainable development

Sterling (2012) argues that the most important role of higher education in the 21st century is 'to develop graduates who are "global citizens" – that is, they better understand how the world works, their own responsibilities, and the sustainability or otherwise of many activities' (p. 11). Studies indicate, however, that the realisation of ESD in higher education has been slower than in primary- and secondary education (Cotton, Bailey, Warren, & Bissell, 2009). Sherren (2006) investigated the integration of sustainability in higher education in Australia and found that it was poorly integrated across the universities, but that it was done in a meaningful way where it was included. Similar studies in Canada showed that the emphasis in both policies and research was on the environment, related to issues such as energy use and waste reduction rather than curricular outcomes (Vaughter et al., 2016; Vaughter, Wright, McKenzie, & Lidstone, 2013). Greening of the university environment seems to be an easier

[7] In 2010, I performed an analysis of Norwegian curricula. I will return to this analysis in Section 3.1.1.

approach than changes to the curriculum, probably because it is easier achieved (Cotton, Warren, Maiboroda, & Bailey, 2007).

The problems of realising ESD in higher education could be due to a praxis where existing courses have been repackaged by substituting the word environment with sustainable development (Parkin, Johnson, Buckland, & White, 2004). It could also be due to the multidisciplinary nature of ESD, which does not coincide with the typical mono-disciplinary organisation of universities (Sherren, 2008), and the current university pedagogies, which emphasises education *about* sustainable development rather than education *for* sustainable development. Shephard and Brown (2017) warn that the risk of ESD becoming normative and undemocratic is particularly high due to the pedagogy in higher education, where the students tend to become passive recipients of normative education rather than 'active agents of participatory learning processes' (p. 763). There is, in other words, need to follow Ryan and Tilbury's (2013) advice of a pedagogical change 'to ensure that [higher education] fulfils its educational purpose in responding to societal needs' (p. 4).

The complex nature of sustainability issues, requires teaching and learning in ESD to be based on a holistic experience, which according to Bosselmann (2001) includes

> [d]iscovery learning rather than reproductive learning; [i]nvestigative learning rather than linear transport of material; [e]xploring reality rather than reading books; [a]ctive learning rather than passive reception of information; [p]roductive action rather than reproduction of facts; [g]aining experience rather than acquiring knowledge. (p.176)

The teaching staff in higher education are not necessarily educated in this kind of pedagogy (Sherren, 2008). On the other hand, Wals and Jickling (2002) argue that ESD 'offers an opportunity for reflection on the mission of our universities and colleges [and] a chance to enhance the quality of the learning process'(p. 221); it includes creating possibilities rather than prescribing the students' futures. ESD provides, in other words, an opportunity for higher education to improve. We do not know what the future looks like, and universities cannot teach *now* for sustainable development *in the future* (S. Gough & Scott, 2007).

Teachers and teacher educators have a crucial role in societal change, as they educate future leaders, professionals and citizens of the world, and help in shaping their learners' worldviews, competencies and attitudes (McKeown & Hopkins, 2002). Teacher education has therefore been seen as the key strategy to embed ESD in schools (Ferreira et al., 2014). However, even though ESD has been included in many school curricula, it is, according to

Evans, Stevenson, Lasen, Ferreira, and Davis (2017), rarely included in teacher education curricula and therefore often disregarded.

Heimlich, Braus, Olivolo, McKeown-Ice, and Barringer-Smith (2004) investigated how EE could be better incorporated into the teacher education curricula in the US. They found great opportunities for integrating EE into the existing materials, but that teacher educators needed to increase their understanding of EE and how it fits into the current systems. Van Petegem, Blieck, and Pauw (2007) followed up on this research and studied the implementation process of EE in two Belgian teacher education colleges. They found lack of integration due to deficiency of knowledge of EE and lack of familiarity with the innovative methodologies. Furthermore, the teacher educators perceived EE as a supplement, and non-science teachers felt that it was the responsibility of the scientists.

Other researchers (e.g. Cotton et al., 2007; Reid & Petocz, 2006) have also revealed ambiguity in higher education academics' understanding of ESD and that environmental factors tend to dominate over social and environmental issues. The same is seen with teachers and pre-service teachers, as well (Burmeister & Eilks, 2013). Moreover, research has shown that teachers and pre-service teachers in chemistry- and science education, despite the positive attitudes, suffered from scarce knowledge on how to actually realise ESD (Burmeister & Eilks, 2013; Burmeister, Schmidt-Jacob, & Eilks, 2013; Sinnes & Jegstad, 2011). Challenges frequently cited as problematic include lack of content and pedagogical knowledge, lack of teaching resources and time constraints due to overloaded curricula and preparation time (Barrett, 2007; McDonald & Dominguez, 2010; Palmer, 1998; Sandell et al., 2003). Burmeister et al. (2013) therefore called for a more thorough realisation of ESD in German teacher education programs. This is in line with findings from Australia where pre-service teacher education programs struggled to realise ESD (Ferreira & Ryan, 2013), and initiatives usually consisted of one, two or three teacher educators working in isolation, instead of coordinated system-wide approaches (Evans, Ferreira, Davis, & Stevenson, 2016).

In a recently conducted literature review, Evans et al. (2017) examined how ESD was realised in pre-service teacher education programs, and the theoretical frames and pedagogical approaches teacher educators drew upon. They found an increasing number of publications addressing ESD in pre-service teacher education. The research reported about place-based methods, experiential methods, inquiry methods and modelling strategies for ESD, but Evans et al. (2017) found the effectiveness of the strategies to be difficult to measure, since the approaches were not described and evaluated properly, an issue also limiting the transferability of the research:

> Some authors appear to assume that pedagogy, or specific types of pedagogies and/or the acquisition of relevant sustainability knowledge and skills, is a catalyst for the development of graduate teachers who will implement [ESD] in schools once they become classroom teachers. It was concerning in these and other cases to note the absence of the affective dimension in authors' discussions of their rationales, conceptual frames or pedagogies. (p. 413)

Ferreira et al. (2014) reviewed 20 initiatives seeking to include ESD in pre-service teacher educations and concluded, in line with Evans et al. (2017), that the initiatives were poorly evaluated. Despite increased number of publications, Evans et al. (2017) summarised ESD in teacher education programs to be:

> still an emerging area of curricular activity driven by individual academics; underpinned by a range of pedagogical approaches and strategies that are uncritically applied; [having] a very small research base, mostly coming from the traditional sources of Australia, the United States and Europe; [and] generally under-theorised and descriptive. (p. 413)

Thus, they emphasised that academics need to work more systemic (i.e. across the whole system until ESD is embedded into the daily teaching) and interdisciplinary with ESD, and engaging more with educational theory.

Littledyke and Manolas (2010) discussed how epistemological, ideological and pedagogical assumptions affect ESD. They concluded by emphasising the need for *post-positivistic* approaches to science education. This includes an epistemology where knowledge is seen as 'a human construct derived from interactive relationships with the world, which can be described by probability rather than certainty, and whole systems are a focus for understanding how their parts interact' (p. 291). Further, their emphasis was on a *reconstructionist* ideology, where education is seen as a process of social change and aims for what the society should be like – rather than the more common *instrumental* ideologies, where the learners are supposed to fit into the current society. Finally, they listed the following features of an effective sustainable pedagogy:

> Learner centred pedagogy in a shared learning community, with multi disciplinary approach, active learning, metacognitive reflection, and meaningful understanding of real world application of ideas. Process led with cognitive/affective integration, with critical, analytical approach to learning and investigation of change strategies to

> identify and promote action for sustainability. Teachers as facilitators, with constructivist approach to scaffold and support learners' investigations. Schools and teachers as models for sustainability. (Littledyke & Manolas, 2010, p. 298)

Learner centred pedagogy is emphasised in ESD since active forms of pedagogy is known to improve the pupils' learning and affective outcomes (Evans, 2015). Cotton and Winter (2010) summarised suitable teaching methods suggested in literature and gave the following list: role plays, simulations, group discussions, stimulus activities, debates, critical incidents, case studies, reflexive accounts, personal development planning, critical reading and writing, problem-based learning, place-based education, fieldwork and modelling good practice.

Fieldwork (or outdoor education used in this thesis) is an often-used additive to the ESD repertoire, which is related to education *in* sustainable development. Outdoor education, and nature encounter in specific, is regarded important for public environmental concern (Malone, 2008; Palmer, 1998). However, Sandell and Öhman (2013) warned against 'an oversimplified belief in a general causal relationship between rich experiences of nature, environmentally-friendly attitudes and behavioural change' (pp. 36-37). They founded their objection in the different motives of outdoor education. When outdoor education has an instrumental motive, outdoor education is used as a mean for different purposes that could have been achieved in other arenas, such as collaboration or ecological knowledge. When the motive on the other hand is intrinsic, the experience is an aim in itself that cannot be achieved in other environments, and the aim is for the learner to develop 'an affiliation with nature' (Sandell & Öhman, 2013, p. 43).

Fägerstam (2014) found that outdoor education was effective, even when just moving outside on the school grounds. Thus, one does not need to travel to a forest or education centre, but one can rather use an 'extended classroom' (e.g. the schoolyard or nearby areas). Within outdoor education, the use of local and environmental issues to contextualise abstract phenomena has been emphasised in order to give the learners a sense of agency and capacity to effect change (Tan & Pedretti, 2010). These educational experiences seek to develop a sense of affiliation with the place, and hence develop care for the environment, and teachers have reported increased enthusiasm and involvement of the learners (Lugg, 2007; Tan & Pedretti, 2010).

2.3 Filling the gap

As we have seen, 2015 was a milestone with the new sustainability aims, but how can we have educational systems follow through? The reviewed studies emphasised the vital role of teachers and teacher educators in societal change, and they give several frames to build upon when planning ESD. However, the reviewed studies have also reported that teachers and teacher educators struggle to realise ESD in their teaching. There is, in other words, a gap between literature and the field of praxis; the literature review shows opportunities and existing guidelines for realising ESD, but it also shows that there is a need for more concrete models and examples of ESD.

Van Petegem et al. (2007) pointed to the varying preferences of teachers; some teachers like to develop their own teaching material, while others prefer readily usable material, especially in the beginning. Hence, it could seem like there is a lack of readily usable material in a form that makes it applicable to the teachers. It could also seem like teacher education programs struggle to give the student teachers adequate preparation. Moreover, the literature review addressed a lack of research on ESD in teacher education programs, and that the current initiatives were poorly evaluated.

In this thesis, I will follow Evans et al. (2017) who called for teacher educators to undertake empirical research that includes critical reflection and evaluation 'in a field that lacks evidence-informed research and where many uncertainties exist about effective approaches' (p. 414). The research is conducted in a Norwegian context, which up to now has no similar studies.

In the next section, I will present a model developed as a part of this thesis, addressing how ESD can be realised in chemistry education. The model is presented in this section since it was used in the analyses and needs to be explained before the methodology chapter. The model will be relate to the previous literature review and to other frameworks for ESD in teacher education programs in Sections 2.3.2 and 2.3.3, respectively.

2.3.1 The elliptic ESD model: a model for chemistry education for sustainable development

Recognising the problems teachers have with realising ESD, and particularly in science education, we developed an ESD model for chemistry education (hereafter referred to as *the elliptic ESD model*). A search for possibilities was the starting point for the development of the model, where our aim was to exemplify how ESD can be realised regardless of the focus and subject workload of existing curricula. The model was developed with this thought in mind and attempts to fill the gap between the school and ‘an ideal and sustainable world’. The question that led our work in developing the model was: what do secondary school pupils need to learn in order to secure sustainable development? The work resulted in Article I and the model presented in Figure 4 below. The model consists of five categories: (1) chemical content knowledge, (2) chemistry in context, (3) the distinctiveness and methodological character of chemistry, (4) ESD competencies, and (5) lived ESD.

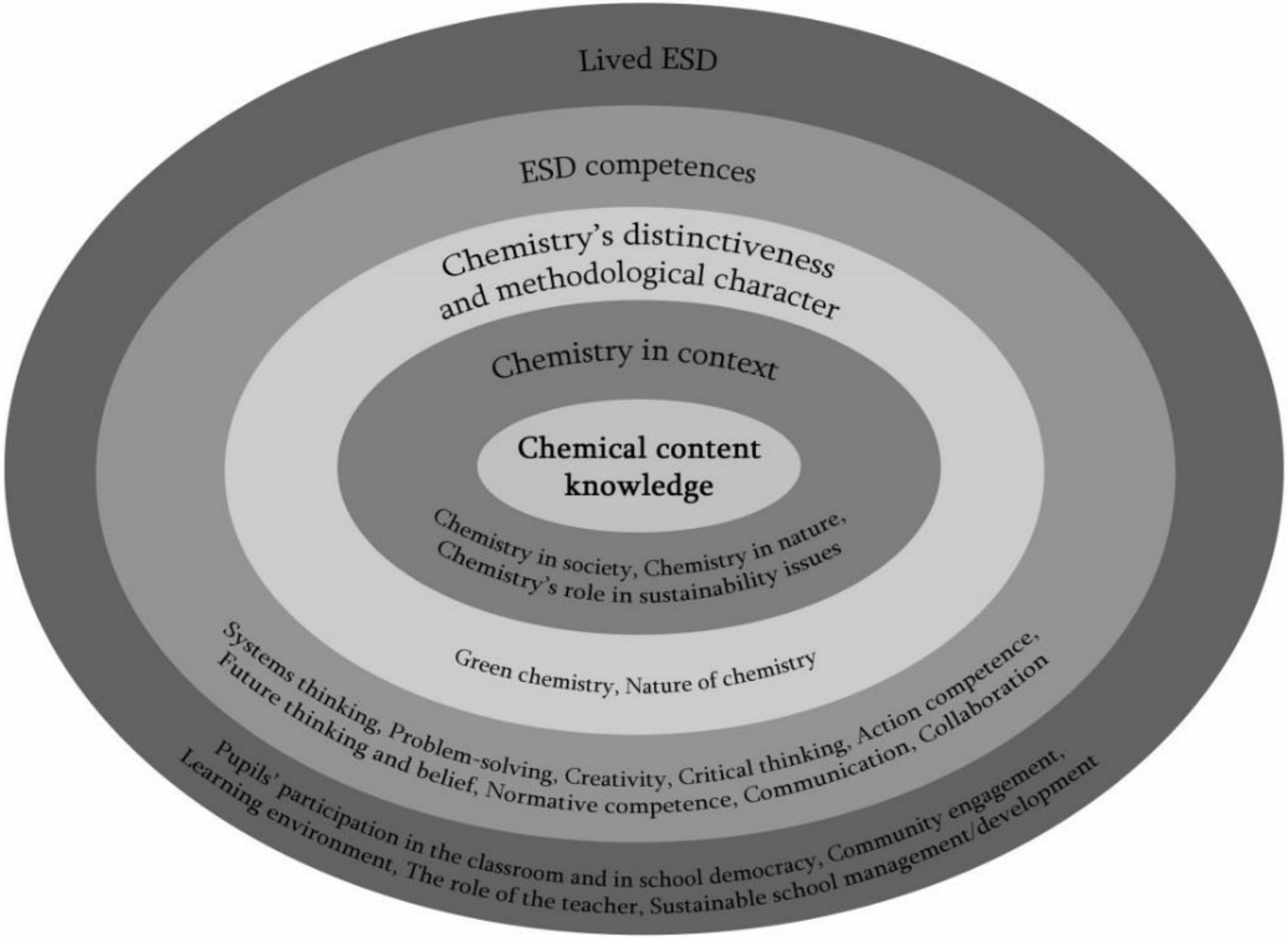


Figure 4. The elliptic ESD model: A model for planning and analysing chemistry education for sustainable development (Jegstad & Sinnes, 2015)

In this section, I will briefly present the five categories, and clarify some issues related to two categories *chemical content knowledge* and *ESD competencies*. The first is emphasised because the role of knowledge in ESD is much discussed, and the latter to reflect on the concept of competencies and clarify three of the competencies. Hence, this section is included both to give a short overview of the model, and to clarify some aspects from Article I. The other categories are more thoroughly described in Article I.

Content knowledge has a core role in the elliptic ESD model, as illustrated by its central location. This is mainly because the model is derived from the already existing subject of chemistry, where content knowledge is largely emphasised (Jegstad & Sinnes, 2015), but also because knowledge is important in order to understand SSIs (Hodson, 2013; Kolstø, 2001), and sustainable development in itself is considered an SSI (Simonneaux & Simonneaux, 2012). Hence, this category mainly concerns education *about* sustainable development and emphasises scientific knowledge that is important for understanding sustainability issues and can be placed within the fact-based tradition.

The role of knowledge in ESD is much discussed, and Kollmuss and Agyeman (2002) pointed to the lack of an apparent correlation between education and pro-environmental behaviour, since more educated people do not necessarily take more environmental actions. However, the opposite is not the case either (Jensen, 2002) and we need to understand the issues in order to make rational choices and content knowledge needs to be a part of ESD. Furthermore, the way we are affected by the knowledge is also linked to our identity and how we perceive the world (Dillon, 2013), as discussed in Section 2.1.2.

Breiting (2007) acknowledged the importance of content knowledge, but he also stressed the frame for working with the content and the level of participation. Hence, both the type of knowledge and the way knowledge is acquired are important in ESD. Moreover, the learners have to be able to assess the knowledge and the reliability and tentativeness of the knowledge (Hodson, 2008; Kolstø, 2000), which is related to other categories of the model.

The second category is *chemistry in context*. ESD should exceed content elements; the learner should also be able to contribute to a more sustainable society, including reflections on ecology, economy and society (Sterling, 2012). Systems thinking is therefore an important issue within this category, emphasising interdisciplinary and holistic thinking, understanding causalities and recognising interdependence between different stakeholders (de Haan, 2010;

Shwartz, Ben-Zvi, & Hofstein, 2006; Wheeler, 2000). Dillon (2012) advocated for the mutual benefits of discussing sustainability issues in science education, since sustainability issues may be perceived relevant for the pupils *and* light is shed on the specific sustainability issue. Outdoor education is also an aspect of this category, and the category is, hence, related to education *in* sustainable development.

The third category is *chemistry's distinctiveness and methodological character* and has two sub-categories, *NOS* and *green* chemistry. The purpose of including NOS, is the previously mentioned need for a post-positivistic approach to science, where knowledge is understood as a human construct (Littledyke & Manolas, 2010). Lederman and Lederman (2012) linked NOS to the following characteristics:

> Scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (involves personal background and biases and/or is theory-laden), necessarily involves human inference, imagination and creativity (involves the invention of explanations), and is socially and culturally embedded. Two additional important aspects are the distinction between observation and interferences, and the functions of, and relationships between, scientific theories and laws. (p. 336)

Kolstø (2000) claimed that 'the human and social aspects of the product of scientific knowledge have been underemphasised in science teaching' (p. 647). He is thereby in line with Letschert (2004) who emphasised the importance of education focusing on methods of knowledge acquisition and meta-cognitive skills rather than emphasising the transfer of knowledge, as the amount of knowledge is so large and 'fleeting'.

Green chemistry includes reflections on how to work sustainable in chemistry. With this regard, the emphasis is both on introducing green chemistry principles (e.g. working on small scale, use environmentally friendly chemicals and waste treatment (Karpudewan, Hj Ismail, & Mohamed, 2011; Ware, 2001)) and philosophical and ethical questions related to development of chemical knowledge and application (Colucci-Gray, Camino, Barbiero, & Gray, 2006).

The forth category of the elliptic ESD model is *ESD competencies*. The concept of competencies has been discussed for more than 50 years in science education (Kauertz, Neumann, & Haertig, 2012), and the development of competencies is highlighted by scholars in the field of ESD (de Haan, 2010; Salganik, Rychen, Moser, & Konstant, 1999; Wiek, Withycombe, & Redman, 2011). A competence approach to ESD is in line with a pluralistic teaching tradition and education *for* sustainable development. It is also in line with Holbrook's (2005) notion of *education through chemistry*, where the educational skills are acquired through the subject. In education through chemistry, the teacher may focus on the teaching and learning approaches in line with ESD, regardless of chemistry topic taught.

The DeSeCo Program (Defining and Selecting Competencies: Theoretical and Conceptual Foundations) investigated the skills and competencies needed for a successful life and a well-functioning society. Rychen and Salganik (2000) reported on this work and pointed to the lack of a broadly accepted definition of the concept competence, and clarified the notion in comparison to skills and knowledge:

> [T]he notion of competencies encompasses cognitive, but also motivational, ethical, social and behavioural components. (…) While the concept of competence refers to the ability to meet demands of a high degree of complexity, and implies complex action systems, the term knowledge applies to facts or ideas acquired by study, investigation, observation, or experience and refers to a body of information that is understood. The term skill is used to designate the ability to use one's knowledge with relative ease to perform relatively simple tasks. (p. 67)

They further contended:

> We recognize that the line between competence and skill is somewhat blurry, but the conceptual difference between these terms is real. Acquiring competencies is viewed as an on-going, lifelong learning process. This process occurs in multiple settings.

The competence approach has been criticised because it risks making ESD a box-ticking exercise (Cotton et al., 2009) or an instrument for a predetermined goal rather than an ongoing process of development (Van Petegem et al., 2007). An emphasis on competencies could also be, depending on the type of competencies, consistent with a product-based rather than process-based outcome of ESD (Varga, Fu, Mayer, & Sleurs, 2007). In this work, the attempt has therefore been to introduce process-based competencies that are specific enough to be realised within the current curricula, and general enough to fit into a future society. Through an emphasis on output (i.e. what the pupils need to learn) rather than input (i.e. what should be taught), several competency frameworks have been developed (e.g. de Haan, 2010; OECD, 2005; Voogt & Roblin, 2012; Wiek et al., 2011). These frameworks informed the definition of the nine competencies included in the model: systems thinking, problem-solving, creativity, critical thinking, action competence, future thinking and belief, normative competence, communication and collaboration.

Wiek et al. (2011) stressed that ESD is not only about mastering each individual competence, it is also about the ability to combine these competencies in a meaningful way. Besides, a set of competencies can form a basis for reflection on the aims of education (Varga et al., 2007). A thorough explanation of the nine competencies is given in Article I. Here, I will explain the role of *action competence* in the model, and clarify our use of the competencies *critical thinking* and *normative competence*, as these competencies have different meanings depending on the context and are used differently in the literature.

Several researchers emphasise the importance of *action competence* (Jensen & Schnack, 1997; Mogensen & Schnack, 2010; Tan & Pedretti, 2010; Weinert, 2001), which according to Mogensen and Schnack (2010) is an educational *ideal.* Mogensen and Schnack (2010) further elaborated: 'As such it is not a goal that can be reached, and even if it is a competence, it is not a specific competence among many others' (p. 60). This is in line with Weinert (2001), arguing that 'action competence includes all those cognitive, motivational, and social prerequisites necessary and/or available for successful learning and action' (p.51). Action competence should therefore, based on this reasoning, have been included as an aim or connection point of the model. This is also the case, since the list of competencies was developed based on the question: 'which competences chemistry learners in secondary school will need in order to support both present future actions for sustainable development' (Jegstad & Sinnes, 2015, p. 665). Thus, all competencies have been described as crucial in order to support *actions* for sustainable development. Nevertheless, we decided to include action competence as a separate competence to make it a more explicit part of the model and to promote an awareness when realising ESD.

The concept of *normative competence* was adopted from Wiek et al. (2011), who linked the concept to justice, equity, social-ecological integrity and ethics. Thus, the term is in line with value-focused thinking and ethical thinking, and must not be confused with being normative. Adomßent and Hoffmann (2013) pointed to ethical thinking in their summary of the *Gestaltungskompetenz*, 'the capacity for empathy, compassion and solidarity':

> There will be no sustainable development if we do not find a much fairer balance between rich and poor, the privileged and the disadvantaged. Repression must be overcome. 'We' must become a global dimensional term. And this will not work without empathy, compassion and solidarity. A global 'we' is the assumption of a common strategy of future-oriented solutions aiming for more justice. Therefore, the development of empathy and its relative value as well as a widened perception of time

> and space in our consciousness are central sub-competencies within the scope of ESD. (p. 6)

Sterling (1996) also pointed to ESD being ethical and that ESD should clarify ethical issues and nurture normative ethical sensibility, and solidarity with others (e.g. people in other parts of the world, future generations and other species). Creating opportunities for learners to reflect on the moral and ethical dimension of ESD is also an emphasised part of the pluralistic teaching tradition (Öhman, 2007).

In the same way that normative competence is not about being normative, *critical thinking* is not about being critical, but rather about assessing information critically. Education that encourages critical thinking is the key to ESD (Sherren, 2006). This is especially important in reviewing information presented in the mass media, where the learners have to be able to assess the information and where it came from, whose interests it represents, what evidence it builds on and how it is evaluated (Cotton & Winter, 2010). The extremities through which science can be communicated to the public range from a focus on the dangers and problems the science has caused at one extreme, to a pure emphasis on the benefits with an exclusion of the risks at the other extreme (Sjöström, Rauch, & Eilks, 2015). The latter is often produced by stakeholders and the learners need critical thinking in order to reveal the ulterior motive.

Lived ESD is the fifth and final category of the model and outlines 'how ESD principles are realised in classroom and school cultures, providing pupils with an opportunity to experience sustainable living' (Jegstad & Sinnes, 2015, p. 673). Sterling (2009) emphasised whole system thinking in ESD, where the sustainability principles were included in the school management. He described sustainable schools as schools where collaboration, flexibility and trust are important, where diversity is valued and where everyone is treated with respect. He also emphasised how pupils could learn how to live sustainable lives by experiencing sustainability initiatives such as energy-saving, waste-sorting, ecological food and school gardens (Sterling, 2009). Other scholars (e.g. Tilbury, 1995) and UNESCO (2006) agree on such a holistic approach, where ESD is the guiding principle of the school and incorporates the school's character, community and place – in line with education *as* sustainable development.

The circular shape of the model illustrates that the categories are 'nested' and interrelated. Through the use of a nested model, the outer categories are emphasised, in the same way as Vaughter et al. (2016) employed a nested concept on the three dimensions of ESD, as described in Section 2.1.1 (‘without a natural environment human beings would not exist, and without a society to create it, there would be no economy’ (p.329)). Even though the categories are interrelated, they can be looked upon as different *layers* of ESD. Lived ESD and ESD competencies represent the general ESD perspectives. These categories can be considered a foundation of all teaching, and a frame in which the other categories are placed – representing the sustainable actions that are the aim of ESD. Furthermore, the three central ellipses represent the subject-specific ESD perspective. The aim of including both general- and subject specific categories is that the model should be neither too oriented to chemistry, and thereby failing to meet the goals of the general education needed in ESD, nor too general, and suffering from lack of approval from chemistry teachers.

2.3.2 An overview of science teacher education for sustainable development

I started Section 2.1 by referring to the use of different prepositions in ESD: education *about*, *for*, *in* and *as* sustainable development. Vare and Scott (2007) presented a similar classification of ESD, using the categories ESD 1 and 2. ESD 1 can be related to education *for* sustainable development, emphasising ‘behaviours and ways of thinking, where the need for this is clearly identified and agreed’ (p. 193). I also relate it to education *about* sustainable development, since it amongst other elements builds on a view that sustainable development can be understood through acquiring more knowledge. ESD 2 is, on the other hand, related to education *as* sustainable development, emphasising capacity-building, sustainable living and open-ended learning, allowing the learners to become critical thinkers who are empowered to take responsibility.

Vare and Scott (2007) concluded the article by stating:

> In this brief paper we have sought to avoid the *either/or*… debate that tends to dominate ESD discourse in favour of a *yes/and*… approach that constantly challenges us to understand *what* we are communicating, *how* we are going about it, and, crucially, *why* we are doing it in the first place. (p.198, original emphasis)

I will take a similar stance with respect to the four prepositions, which I chose to use because I found them to be the most specific and thorough division of ESD. In line with Vare and Scott (2007) viewing ESD 1 and 2 as a yin and yang of ESD, I find the four prepositions to be complementary. The boarders between the prepositions are sometimes factitious and blurry, but all of them are needed to address all perspectives of ESD. Education *about* sustainable development is needed to understand sustainability issues, and also the other perspectives on

ESD; education *for* sustainable development is important to develop capacity and relevant competencies; experiences *in* the environment is important to relate to it; and education *as* sustainable development is a way of internalising the learning.

Seeing the perspectives addressed in the review in relation to each other and these four prepositions, I created an overview for science teacher education for sustainable development, as illustrated in Table 1. The dashed lines between *for* and *in/as* illustrate the blurry boarders, but also that the two latter feed into the first and, hence, can be seen as a part of a large whole. Otherwise, the overview shows that the current perspectives address most aspects of ESD, but with less outspoken emphasis on education *in* sustainable development. The normative teaching tradition is not included in this overview since it is not in line with the view of ESD presented in this thesis, due to the danger of indoctrination. The five categories of the elliptic ESD model are included in the overview and highlighted with blue letters. The distribution of the categories from the elliptic ESD model is more specific than the other frameworks, as shown in the table.

Table 1: A schematic overview of elements related to science teacher education for sustainable development. The overview is developed based on the previous literature review

<table>
<tr><th colspan="2"></th><th>About</th><th colspan="2">For</th><th>In
As</th></tr>
<tr><td rowspan="6">Science teacher education</td><td rowspan="5">Science education</td><td>Theoretical knowledge about sustainability issues</td><td colspan="2">Attitudes, values, capacity building, critical thinking, competencies</td><td>Education in the environment
Sustainable living
Democracy</td></tr>
<tr><td>Fact-based teaching tradition</td><td colspan="3">Pluralistic teaching tradition</td></tr>
<tr><td colspan="3">ESD 1</td><td>ESD 2</td></tr>
<tr><td>Content knowledge</td><td>Science's methodological character</td><td>ESD competencies</td><td>Science in context
Lived ESD</td></tr>
<tr><td colspan="2">A post-positivistic approach to science education</td><td></td><td></td></tr>
<tr><td>Pedagogical education</td><td colspan="3">Learner centred pedagogy, multidisciplinary approaches, active learning, metacognitive reflection, real world application</td><td>Outdoor education
Education seen as a process of social change
Teachers as facilitators
Schools and teachers as models for sustainability</td></tr>
</table>

2.3.3 A framework for analysing science teacher education for sustainable development

Even though the elliptic ESD model originally was created as a tool for teachers to realise ESD in their chemistry teaching, it was used to analyse the realisation of ESD in the teacher education program under study. There have been several multi-national initiatives addressing ESD. Two relevant frameworks for ESD in teacher education resulting from this work that could have been used instead are the CSCT (Curriculum, Sustainable development, Competences, Teacher training) framework (Sleurs, 2008) and the UNECE (United Nations Economic Commission for Europe) framework (UNECE, 2011). I will in this section address why I chose to use a model developed for secondary schools to analyse teacher ESD rather than the two frameworks mentioned.

The CSCT framework was developed as a part of the ENSI (Environment and School Initiatives) project[8] to offer curriculum models to teacher education programs aiming to realise ESD (Sleurs, 2008). In the framework, visualised in Figure 5, the authors included three levels. In *the professional dimensions*, teachers are envisaged in a dynamic relationship with their pupils, colleagues and wider society as illustrated by the blue triangle. The second level consists of three *overall competencies for ESD*: teaching, reflecting/visioning and networking, emphasising competence acquirement to be a self-steered and active process. Third and finally, there are *five domains of competencies*: values and ethics, action, emotions, system thinking and knowledge. The triangles are regarded twistable in order to emphasise that the five domains should be applied to both the professional dimensions and the overall competencies (Sleurs, 2008).

[8] The ENSI project is an international network started by the Organisation for Economic Development and Cooperation (OECD), which aims to support the realisation of ESD in the whole educational system through research based projects (ENSI, n.d.).

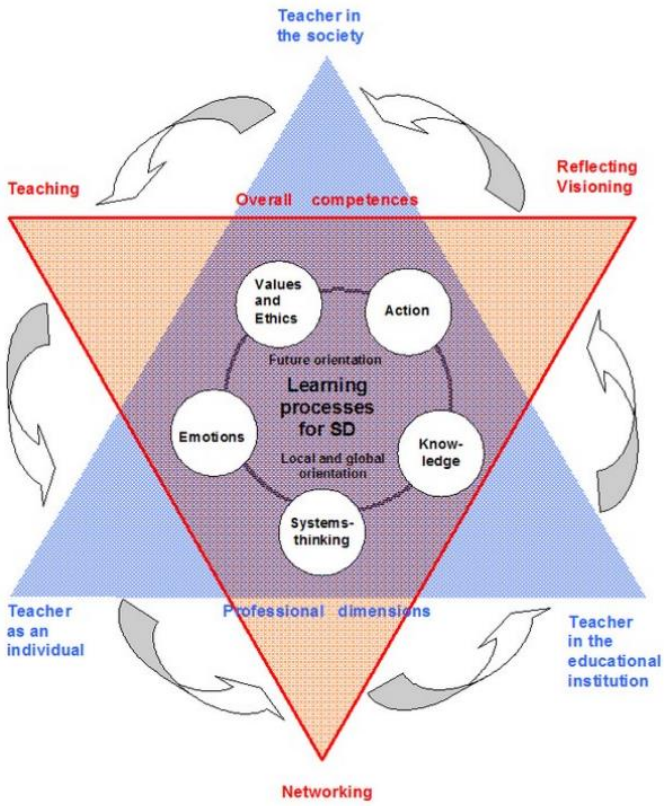


Figure 5: The CSCT framework. A dynamic model for ESD competencies in teacher education (Sleurs, 2008)

The UNECE framework (2011) was developed by an international Expert Group appointed by UNECE, and consists of 40 core competencies in ESD for educators. The framework is a guide to: (1) what educators should *know* (the educator understands…), (2) what they should *be able to do* (the educator is able to…), (3) how they should *live and work with others* (the educator works with others in ways that), and (4) how they should *be* (the educator is someone who…). The competencies are sorted in these four categories, and further divided between the following three characteristics of ESD: holistic approach (integrative thinking and practice), envisioning change (past, present and future) and achieving transformation (people, pedagogy and education systems), as shown in Figure 6.

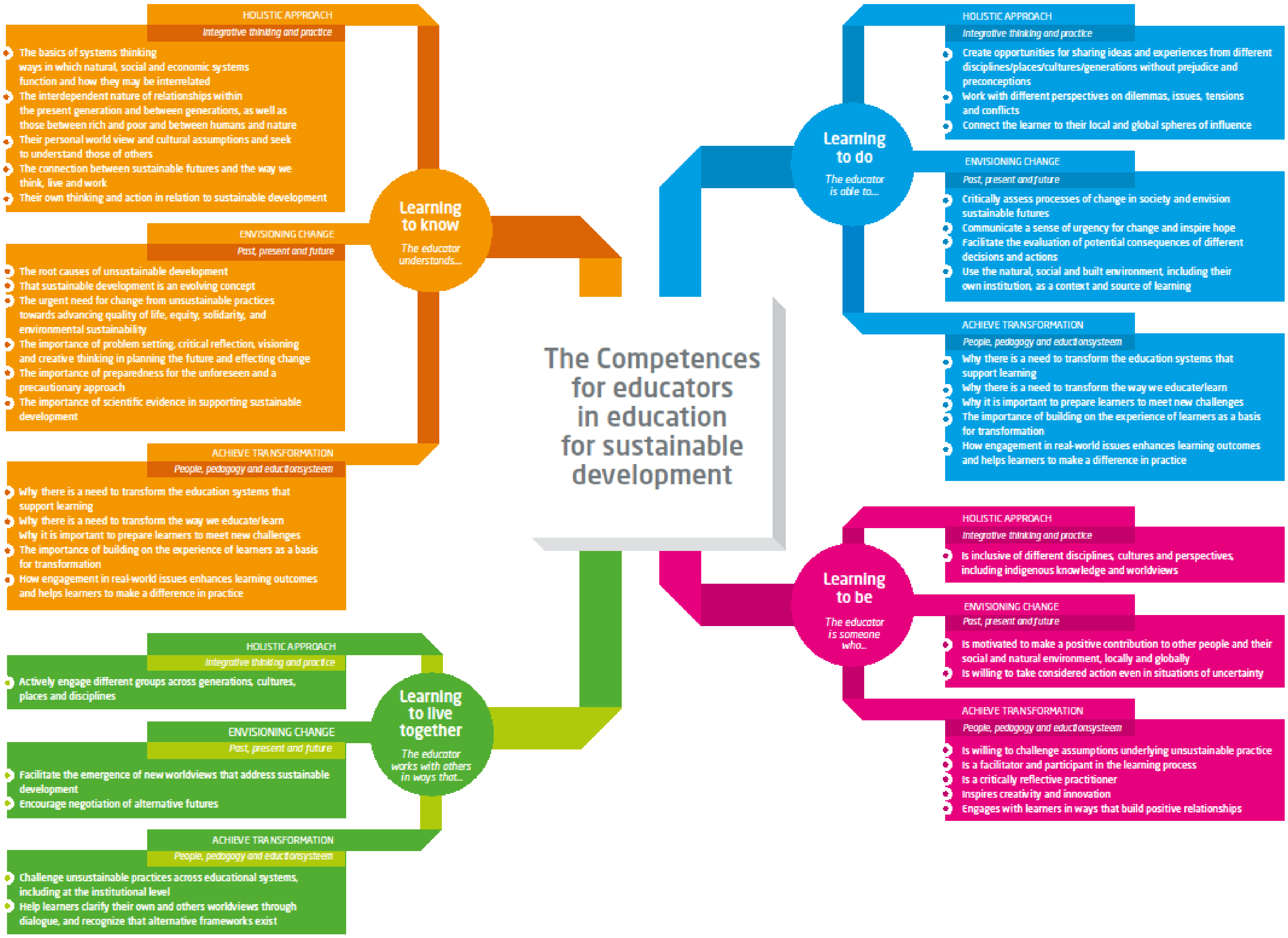


Figure 6: The UNECE framework. Competencies for educators in education for sustainable development (UNECE, 2011)

Comparing the two frameworks, both include the knowledge dimension and thereby education *about* sustainable development. Otherwise, they are quite different. The CSCT framework is a rather broad framework, which emphasises education *for* sustainable development through a focus on action, reflection, systems thinking, emotions, values and ethics. Further, it places a large emphasis on education *as* sustainable development through the professional dimension and the emphasis on networking. The core competencies in the UNECE framework are on the other hand much more specific and content-oriented. Thus, even though it presents ESD competencies related to most categories in the overview, as illustrated in Table 2, all core competencies are related to sustainability issues. The core competencies do, in other words, not support an education through science perspective, which is a founding perspective of this thesis.

Table 2: A schematic overview of elements related to science teacher education for sustainable development – extending Table 1 to include the CSCT and UNECE frameworks

		About	For		In / As
Science teacher education	Science education	Theoretical knowledge about sustainability issues	Attitudes, values, capacity building, critical thinking, competencies		In: Education in the environment As: Sustainable living Democracy
		Fact-based teaching tradition	Pluralistic teaching tradition		
		ESD 1			In: As: ESD 2
		Content knowledge	Science's methodological character	ESD competencies	In: Science in context As: Lived ESD
		A *post-positivistic* approach to science education			
	Pedagogical education	Learner centred pedagogy, multidisciplinary approaches, active learning, metacognitive reflection, real world application			In: Outdoor education As: Education seen as a process of social change Teachers as facilitators Schools and teachers as models for sustainability
	CSCT	Knowledge	Teaching and reflecting/visioning Systems thinking, emotions, ethics and values and action		In: As: Networking The professional dimension
	UNECE	Learning to know Learning to do (5 last competencies)	Learning to do (7 first competencies) Learning to live together (2nd, 3rd and 5th competencies)		In: As: Learning to know Learning to live together (1st and 4th competencies)

Another aspect of the models presented is that they emphasise the educators and their competencies, without focusing on the pupils. In Section 1.2, I pointed to how the teaching in teacher education programs needs to be close to what pupils learn in school and that one cannot say how a teacher can realise ESD without starting out with the pupils' learning in mind. This view is in coherence with an attempt to bridge theory and praxis through more school-based teacher education programs (Korthagen, 2011; Korthagen & Kessels, 1999). Teacher education programs have for long been criticised for not being sufficiently relevant for practices in school and several student teachers struggle with the transferability from the teacher education program to the school context (Ashton, 1996; Korthagen, 2011). With this respect, I found the CSCT and UNECE frameworks to be too far away from the reality in schools and I chose to develop a more school-based analytical framework.

The benefits of using the elliptic ESD model as an analytical tool instead of the other suggested frameworks were that we got a specific model, developed in line with the school system under investigation, within an education *through* science perspective that could identify the ESD realisation even when ESD was not an explicit focus of the teaching sessions. We have therefore adapted the elliptic ESD model developed for schools to teacher education programs. Indeed, literature and the two models informed this adaptation. I will return to a discussion of the elliptic ESD model as an analytical tool in Sections 4.4.5.

3 The empirical context

The two empirical articles in this thesis are based on a case study at NMBU. In this section, I will first present the Norwegian context and thereafter the university and the teacher education institution where the case study took place. I will also present the context of the articles.

3.1 The Norwegian context

Norway has played a positive and highly profiled role internationally with respect to the sustainability agenda (Lafferty, Knudsen, & Larsen, 2007; Langhelle, 2000). This is mostly due to Brundtland's role as Chairperson for the Brundtland commission, and the involvement of Norwegian politicians and leaders in the preparation for the Earth Summit in the same time period (Lafferty et al., 2007). Norway has, however, been accused of being better at promoting sustainable development internationally than at home: 'Norway increasingly developed [a sustainable development] that was "bifurcated": very active and morally pretentious in international environment-and-development arenas, and increasingly passive and non-consequential in fronting and promoting [sustainable development] at home' (Lafferty et al., 2007, p. 186). A reason for the lack of priority in Norway could be the Norwegian oil industry and the strong link between the petroleum industry and the Norwegian economy and politics, which can further be coupled with a typical Norwegian understanding of the sustainability concept, emphasising sustainable economic growth (Straume, 2016).

Through participation in the Decade and other international agreements on sustainable development, Norway is obliged to include ESD in the school system. The realisation of ESD has, however, been criticised (Laumann, 2007; Sinnes & Eriksen, 2016; Sinnes & Jegstad, 2011; Sundstrøm, 2016), and Straume (2016) found it to be scattered and confined. Andresen, Høgmo, and Sandås (2015) questioned whether our long traditions for outdoor education have made us believe that we are better at realising ESD than we actually are. Nature has, traditionally, played an important role in the lives of the Norwegian people; we use the nature for vacations, exercises, recreation and as an arena for teaching and learning (Frøyland, 2010) – and Norway is recognised internationally as country with strong outdoor traditions (Henderson & Vikander, 2007). Nature is also emphasised in *the environmental article* of the Norwegian constitution, quoted in Box 1 below.

> **Kongeriket Norges Grunnlov, §112:** *Enhver har rett til et miljø som sikrer helsen, og til en natur der produksjonsevne og mangfold bevares. Naturens ressurser skal disponeres ut fra en langsiktig og allsidig betraktning som ivaretar denne rett også for etterslekten. Borgerne har rett til kunnskap om naturmiljøets tilstand og om virkningene av planlagte og iverksatte inngrep i naturen, slik at de kan ivareta den rett de har etter foregående ledd. Statens myndigheter skal iverksette tiltak som gjennomfører disse grunnsetninger.*
>
> **The Norwegian Constitution (as laid down on 17 May 1814 by the Constituent Assembly at Eidsvoll and subsequently amended, most recently in May 2014), Article 112:** *Every person has the right to an environment that is conducive to health and to a natural environment whose productivity and diversity are maintained. Natural resources shall be managed on the basis of comprehensive long-term considerations which will safeguard this right for future generations as well. In order to safeguard their right in accordance with the foregoing paragraph, citizens are entitled to information on the state of the natural environment and on the effects of any encroachment on nature that is planned or carried out. The authorities of the state shall take measures for the implementation of these principles.*

Box 1: The environmental article of the Norwegian constitution

Despite the long traditions for outdoor education in Norwegian, Andresen et al. (2015) argued that the transition to ESD had been challenging. A problematic tendency pointed to is that the realisation of ESD in Norway to a large extent is left to natural science[9] (Andresen et al., 2015; Sinnes & Straume, 2017; Straume, 2016). However, Parkin et al. (2004), reminded us that 'there is no single home for sustainability. It doesn't belong to any specific academic discipline or school subject line (…) it is more helpful to think of sustainable development as a non-discipline' (p. 18).

There are different opinions on how well established ESD is in the Norwegian curricula, despite emphasis in constitutional documents such as the Norwegian constitution and the Education Act stating that 'the pupils and apprentices shall learn to think critically and act ethically and with environmental awareness. They shall have joint responsibility and the right

[9] An interdisciplinary subject taught in year 1 to 11, which includes chemistry, physics, biology and parts of the geosciences. An overview of the educational system in Norway can be found at http://www.udir.no/globalassets/upload/brosjyrer/5/education_in_norway.pdf

to participate' (Ministry of Education and Research, 2016a). In the next section, I will present the Norwegian curricula and discuss the possibilities for ESD they provide.

3.1.1 The curricula

All subjects taught in Norwegian schools are governed by the national core curriculum, which runs throughout the school system from years 1 to 13 (Royal Ministry of Education, 1994). The subjects are also governed by specific subject curricula (Directorate for Education and Training, 2010). The revised subject curricula were introduced early in the UN decade of ESD, and there was an intention that ESD should be integrated in all subject curricula (Sandås & Isnes, 2015). Despite this intention, the curricula and the formal secondary education in Norway has been accused of not prioritising ESD (Andresen et al., 2015; Brænden, 2008; Koller, 2009; Laumann, 2007; Raabs, 2010; Schreiner, 2006; Sinnes & Straume, 2017).

The formal curricula in Norway are acknowledged as quite flexible in terms of room for interpretation of the competence aims, but research shows that time constraints hinder the teachers in using the opportunity to increase the extent of ESD (Andresen, 2007; Sinnes & Jegstad, 2011). Research also shows that the teachers mainly teach with a foundation in the competence aims and fail to include the introductory parts of the subject curricula and the core curriculum since they are not subject for assessment (Andresen, 2007; Brænden, 2008).

The Norwegian core curriculum has been praised by scholars in the field of environmental education (Andresen, 2007) and Palmer (1998) commended the balanced incorporation of education *in, about* and *for* the environment in the curriculum. In a comparative study of ESD in Scottish and Norwegian primary schools, Andresen (2007) linked the core curriculum to a perspective of ESD, which S. Gough and Scott (2006, p. 275) called *the paradigm shift,* thinking that 'sustainable development requires nothing less than a revolution in the ways we think about, and live, our lives'. The subject curricula was on the other hand linked to *the technocratic perspective*, which focuses on specific problems of sustainable development that can be solved through the development of scientific and technological solutions; in a technocratic view, the science that also caused the problem is thought to solve it (S. Gough & Scott, 2006).

The core curriculum has also been mentioned as the forerunner for the competency-based development of education:

> In Norway educational reform began in 1993 with a consecutive curriculum that promoted the integration of a diversity of human features. The perspective of the Norwegian curriculum was and is an integrated and balanced person, who is able to take responsibility for himself, herself and others, who is able to work and study with perspective and understanding, and who has the ability and willingness to take on new challenges. This Nordic curriculum can be considered as a precursor of the contemporary emphasis on competence-based development in education and schooling. (Letschert, 2004, pp. 20-21)

In 2010, I performed, on behalf of the Norwegian Centre for Science Education, an analysis of the curricula in Norwegian, English, social science and natural science. In the analysis, I differentiated between education *about* sustainable development and education *for* sustainable development. The results of my analysis (The Norwegian Centre for Science Education, 2010) were in line with Andresen (2007) and revealed that the core curriculum emphasised education *for* sustainable development, while the subject curricula, and especially the one in natural sciences, mainly emphasised education *about* sustainable development. There were some aspects of education *for* sustainable development in the *objectives of the subject* in the introductory section, but the intentions were not followed up in the aims (The Norwegian Centre for Science Education, 2010).

Looking closer at the chemistry curriculum,[10] I find the same distinct focus on the environment and sustainable development in the introduction. Topics include the role of chemists in the development of relevant fields (e.g. environmental science, new materials, new energy sources); how chemical research, methods and material both affect and have the possibility to reduce strain on the environment; and chemical research's significance on technology and economic development (The Norwegian Directorate for Education and Training, 2006). Despite this focus in the introductory section of the curriculum, no further suggestions for how ESD can be realised as a part of the chemistry subject is given, and the role of ESD is not prevalent in the competence aims. Moreover, the focus in the introductory section illustrates the importance of chemical research and chemical knowledge in society, but the view of the role of chemistry is still technocratic. These findings coincide with Vesterinen, Aksela, and Sundberg (2009), who found that the Norwegian chemistry

[10] Chemistry is taught as a separate subject in year twelve (Chemistry 1) and in year thirteen (Chemistry 2).

curriculum defined the role of chemistry in society at an instrumental level where the focus is on chemistry as a tool to produce new applications.

Sandås and Isnes (2015) wrote about ESD in the Norwegian school system and pointed to how the intentions and the interpretation of the curricula may differ based on the background of the reader. Thus, different readers may perceive ESD differently realised. With foundation in the analyses, I recognise this discrepancy; I agree to some extent with the challenges pointed to by the researchers, but I still see the potential for realising ESD due to the flexibility the curricula provide and the possibilities given, especially in natural science. However, the technocratic and instrumental approach in chemistry education demands more from the teacher, and in turn the teacher education program. This concurs with research showing that the realisation of ESD in Norway, regardless of subject, to a large extent is dependent on the teacher and ardent souls (Andresen, 2007; Sundstrøm, 2016), and it accentuates the need for an emphasis on ESD in teacher education programs.

3.1.2 Teacher education

There are four kinds of pre-service teacher education programs in Norway: a one-year post-graduate teacher education program (PPU) for candidates with a vocational or academic educational background; a five-year program (LUR[11]) where teacher education and academic studies are integrated throughout the five years, a four-year general teacher education program educating teachers for primary schools and a four-year general teacher education program educating teachers for year 5 to 10. PPU and LUR, which are the programs offered at NMBU, educate teachers for year 5 to 13.

In the national document giving the guidelines for PPU and LUR (i.e. *Rammeplanen*), sustainable development is mentioned in the main topic area 'the teacher and the community'. Based on a societal perspective, the teacher is supposed to explain and develop his or her academic understanding and pedagogical practice, and one of the aims is that the student teachers 'shall have insight into the environmental consequences of practice of their

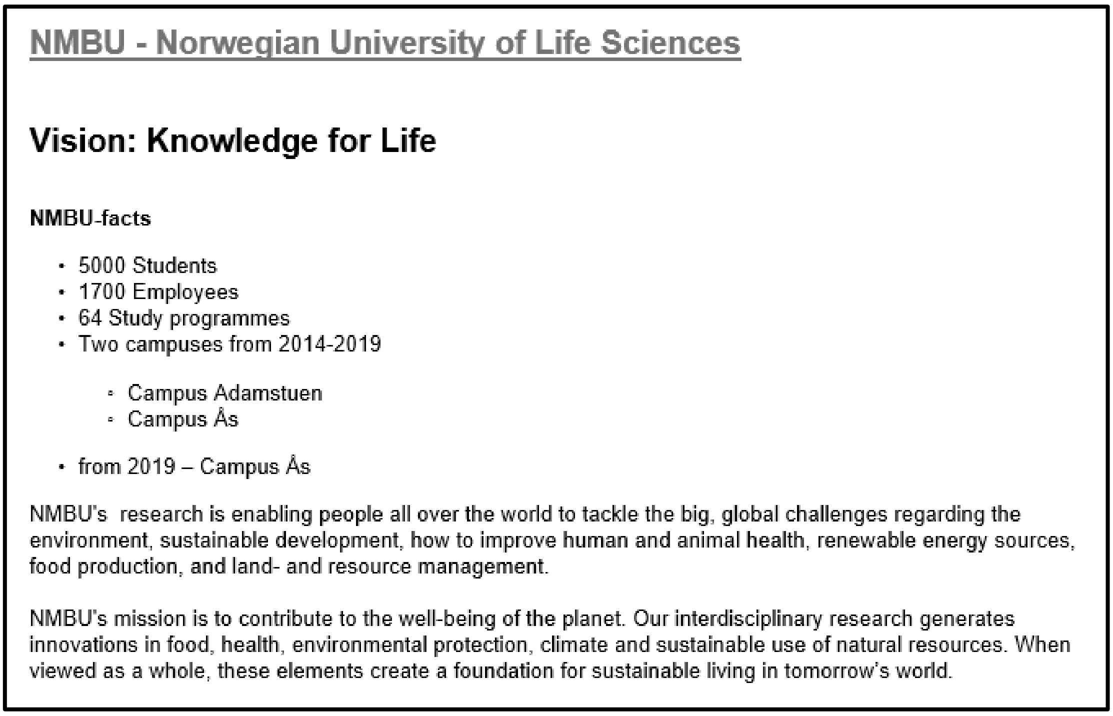
[11] The program has different abbreviations at the different universities and LUR is the abbreviation used at NMBU.

profession or vocation and encourage changes that may be conducive to an ecological and sustainable development' (Ministry of Education and Research, 2003, p. 19).

Founded in their experience of guiding teachers in 'the Sustainable backpack', a major ESD initiative from the Norwegian government (The Norwegian Centre for Science Education, 2015), Misund, Husby, Munkeby, Fjørtoft, and Jordet (2014) claimed that the role of ESD in teacher education programs is not clear enough and that the student teachers are not sufficiently educated to follow up on ESD. They therefore asked for clearer political guidance within ESD in schools and teacher education programs. There are possibilities and the new Report to the Norwegian Parliament (Ministry of Education and Research, 2016b) is a step in that direction, emphasising in-depth knowledge and interdisciplinary topics such as sustainable development. Further, the Report to the Norwegian Parliament indicates a change in the curricula in order to make the whole curricula and not only the competence aims valid in the assessment. The core curriculum will be changed in this work, but the value foundation it has been acknowledged by is said to be kept. The major changes will rather include suggested pedagogy and the links between the curricula. Thus, this work provides large possibilities in guiding the ESD work, but the challenge has to be taken seriously.

3.2 Description of the case

The case consisted of the one-year post-graduate teacher education program at NMBU. In this section, I will first give a background description of the university before I go into detail on the context of Articles II and III.



NMBU - Norwegian University of Life Sciences

Vision: Knowledge for Life

NMBU-facts

- 5000 Students
- 1700 Employees
- 64 Study programmes
- Two campuses from 2014-2019
  - Campus Adamstuen
  - Campus Ås
- from 2019 – Campus Ås

NMBU's research is enabling people all over the world to tackle the big, global challenges regarding the environment, sustainable development, how to improve human and animal health, renewable energy sources, food production, and land- and resource management.

NMBU's mission is to contribute to the well-being of the planet. Our interdisciplinary research generates innovations in food, health, environmental protection, climate and sustainable use of natural resources. When viewed as a whole, these elements create a foundation for sustainable living in tomorrow's world.

Figure 7: Screen-shot from NMBU's webpage (NMBU, 2015a)

NMBU is one out of eight universities in Norway. The university was established in 1859 as the Norwegian Agricultural Postgraduate College and is the second oldest institution of higher education in Norway. In 1897, the college became a scientific university college known as Norwegian College of Agriculture,[12] which had in total 32 first year students, distributed in five different study programs (agriculture, forestry, horticulture, dairy science and land consolidation). The educational institution emphasised research and the number of study programs increased gradually until the institution achieved the status as a university and became Norwegian University of Life Sciences[13] in 2005. In 2014, the university was merged with the Norwegian School of Veterinary Science,[14] and today 64 study programs are offered to more than 5000 students.

The teacher education programs at NMBU are fairly new, but still have long traditions. In 1915, the first Norwegian teacher education program targeting agricultural advisors and smallholding teachers was established. NMBU was given the responsibility for this teacher

[12] Norwegian name: Norges Landbrukshøgskole, NLH
[13] Norwegian name: Universitetet for miljø og biovitenskap, UMB
[14] The Norwegian name was changed to Norges miljø og biovitenskapelige universitet, NMBU

education program in 1965 and teacher education was offered until 1990. The program was terminated in 1990, but started up again in 1999 as PPU. Since 2004, NMBU has offered both PPU and LUR. The teacher education programs amount to 60 ECTS credits (one year in the university) and is offered in science education, mathematics education and agricultural education. Approximately 100 teachers graduate each year within one or more of the fields. SLL is responsible for the teacher education part of the educational program; student teachers in the LUR-program are therefore educated in the natural sciences in other divisions and departments at the university, while the student teachers attending PPU already possess a bachelors-, masters- or doctoral degree in a scientific subject, mathematics or agriculture.

Founded in the agriculture traditions, sustainable development is an important issue at NMBU, as illustrated in Figure 7. In the societal mission of the university it is stated that

> NMBU shall take particular responsibility for research that addresses the major global issues of environment, sustainable development, human and animal health, climate challenges, renewable energy sources, food production 'from land and fjord to the table', and land and resource management issues. (NMBU, 2015b, p. 7)

There are ambitious goals for the teacher education program as well, and SLL has explicitly stated an overall aim to educate teachers who can contribute to sustainable development:

> The pupils of today are the citizens of tomorrow. We therefore have an overall aim for the teacher education program to educate teachers who can contribute to sustainable development. We want to educate teachers who facilitate for the pupils to develop knowledge, competencies and attitudes in understanding, and using nature in a way that has long-term sustainability and builds on a societal understanding. Mathematics, the sciences and agriculture are therefore seen in social, cultural, economic and ecological contexts in the teacher education program. The aim is that the pupils should be able to use what they have learnt in sustainable development. (NMBU, 2009, p. 6, my translation)

Despite the emphasis on sustainable development at NMBU, the external evaluation committee found that the concept was interpreted in different ways throughout the university (Dolin et al., 2012).

In the next sections, I will, first, present the theoretical perspectives of the teacher education program at NMBU. I will thereafter present the contexts of the two articles. The research participants are presented in the methodology chapter, since this part also includes methodological reflections. When I write *NMBU* in these sections and the remainder of the extended abstract, I am referring to the teacher education program at NMBU and not to the university as an entity.

3.2.1 Theoretical perspectives of the teacher education program at NMBU

> In PPU, you are involved with thoughts, feelings and your body (Gjøtterud, Jónsdóttir, & Strangstadstuen, 2011, p. 1, my translation)

The theoretical perspectives utilised in the teacher education program are based on a sociocultural perspective on learning (Lave & Wenger, 1991; Vygotsky, 1978), emphasising a social community and collaboration as a part of teaching and learning (Gjøtterud, 2011). Many of the teacher educators also emphasise experiential learning theory (Dewey, 1938). Within science education, Dewey's ideas about education have been used to advocate experience and various forms of student-active learning, including, inquiry-based learning, laboratory work and outdoor schooling (Wong & Pugh, 2001). However, according to Dewey, educative experiences do not emerge from student activity (e.g. projects, group-work) or a particular environment (e.g. labs, field trips), but in transformative experiences that are valuable in themselves and that can lead to other valuable experiences (Wong & Pugh, 2001). The approach to experiential learning taken at NMBU is therefore both related to both active pedagogy and reflective learning (Gjøtterud, 2011).

The opening quote of this section is from the preface of a literature collection studied by the student teachers in pedagogy and illustrates another important quality of the teacher education program at NMBU; the aim is that the student teachers should be involved as holistic human beings in the educational program. Some of the teacher educators have a background in gestalt-oriented or confluent education (Grenstad, 1986), which influences the teacher education program (Gjøtterud, 2011). Confluent education is founded in experiential learning theory and is a holistic pedagogy where the intellectual, emotional and psychometric perspectives are merged (Grenstad, 1986). Every pupil is considered unique and the education should be inclusive and make sure that all pupils are allowed to develop their potential. According to Grenstad (1986), responsibility is a central element of confluent education; the values should not be forced on the learners, but they should rather be stimulated in order to be aware of their own values. Thus, the aim is to facilitate for the individual learner to get optimal development and growth in order to take care of him- or herself and others in a wider context. Confluent education is, in other words, in line with ESD-principles, both related to Sterling's (2009) emphasis on the whole person and the emphasis on empowerment of the learners.

The teaching at NMBU includes active teaching approaches such as *inquiry learning, phenomenon-based teaching* and *outdoor education*. Inquiry learning is related to methods that support the pupils in learning about scientific inquiry and in developing knowledge of science concepts and NOS through an inquiry process (Crawford, 2014). The focus on inquiry learning builds on the action research project StudentResearch (Bjønness & Kolstø, 2015; Knain & Kolstø, 2011), which aimed to enhance pupils' inquiry practices. The approach to inquiry learning taken at NMBU is with a focus on socio-scientific issues (Kolstø, 2001) and therefore also includes critical thinking and multiple perspectives. Further, phenomenon-based teaching emphasises the pupils' encounter with the phenomenon and the challenge that lies within connecting the phenomenon to relevant knowledge and inductive education (Dahlin, Östergaard, & Hugo, 2009; Østergaard, Dahlin, & Hugo, 2008). Finally, the emphasis on outdoor education is informed by research on school gardens and farms (Jolly & Krogh, 2011; Krogh & Jolly, 2012), as well as the phenomenological approach.

The teaching is also influenced by the other programs offered (i.e. agriculture and mathematics), since many teaching sessions are held jointly. This influence is particularly noticeable between science and agriculture, where the student teachers in science education experience teaching sessions that are founded in an agricultural tradition – and vice versa. Sund (2008) introduced the concept of socialisation content, which he refers to as the context in which subject content is taught and developed into meaning and he emphasised how meaning is affected by the socialisation content the teacher brings. At NMBU, group work and plenary discussions are highly included as a part of the teaching. Since many teaching sessions are held jointly between the programs, science teachers learn how to contextualise and concretize their teaching from the vocational students. Thus, both the lecturers' and the fellow student teachers' socialisation content affect the learners.

Furthermore, NMBU has close collaboration with schools focusing on ESD where the student teachers can carry out parts of their practical training. In order to gain a more global perspective, the student teachers are also encouraged to take parts of their practical training in a developing country. Each year, a group of student teachers travels to Malawi for four weeks of practical training and they present their experiences and reflections to the other student teachers afterwards.

3.2.2 The science teacher education program in 2011/2012

I was involved in the case over three years and started out with a broad perspective. However, in the articles, I chose to look at the empirical material directly relevant to the teacher education program, only, and to follow the student teachers in science education (i.e. I excluded the sections relevant to the student teachers in mathematics and agriculture, only). In Article II, we analysed the ESD focus in the science teacher education program in the academic year 2011/2012.

The program was organised through twelve weeklong *modules*; six of these modules were in science education while the remaining six were in pedagogy.[15] Descriptions of each science education session analysed and each pedagogy module are given in Appendix 1. In addition to the twelve modules, the student teachers have twelve weeks of practical training and some mandatory assignments: two individual assignments in science education, one individual exam preparative assignment in science education and pedagogy (combined) and one group assignment in pedagogy. Three of the assignments were included in the data corpus: one science education assignment, where the student teachers chose an issue within science education to discuss; the exam preparative assignment, where the student teachers in a combined science education and pedagogy assignment reflected on their development as teachers; and the pedagogical assignment, where the student teachers worked in groups on a pedagogical development project with the aim of improving or suggesting improvements in educational practices.

3.2.3 The residential field course at Finse in 2012

In Article III, we analysed the residential field course at Finse in 2012. On the first day, a teacher educator introduced teaching in the mountain area founded in an art exhibition called ‘Imagine being here now’. Distractions can take you away from where you are and there are, hence, different ways of being in a place. Thus, the stated goal for the excursion was to be at Finse as science and mathematics teachers, and the student teachers were encouraged to think about the surroundings with their subjects in mind and think about which parts of the surroundings they could use for teaching. The ability to spot or create subject issues in an outdoor context was therefore an important element of the field course. The student teachers

[15] The first three modules are now pedagogy and science education combined.

were also prepared for their practical training, i.e. how to prepare teaching and how to encounter and guide the pupils.

All sessions are described in the article.

4 Methodology

In this chapter, I will consider the methodological issues of my research and the chapter comprises four sections. Firstly, I will give an account of the research design and the project participants. Secondly, I will provide a description of the data corpus, including a brief description of the development of the PhD-project. Thirdly, I will provide an account of the analytical procedures that have been used in the thesis. Fourth and finally, I will reflect upon research credibility and the validity and limitations of the research. The research process is described from a personally engaged perspective and I will reflect on both strengths and weaknesses of the process throughout the chapter.

4.1 Research design

The research design is based on a *case study method*. According to Yin (2009, p. 18), 'a case study investigates a contemporary phenomenon in depth and within its real-life context', and it is applicable when how and why questions (explanatory questions) are posed, such as in this project. The one-year teacher education program for candidates with an academic or vocational educational background in science, mathematics and/or agriculture at NMBU constituted the case.

Using Stake's (2000) classification of case studies, we can classify this case study as an *intrinsic case study*, i.e. a case study that is primarily undertaken because the case itself is interesting. The case had certain *instrumental* characteristics (Stake, 2000) as well, due to the insight in teacher education for sustainable development and the possibilities of theory building that the case provides. A researcher can have several interests, thus, 'there is no line distinguishing intrinsic case study from the instrumental; rather, a zone of combined purpose separates them' (Stake, 2000, p. 437).

With time, the need for a theoretical framework became clear and, consequently, the instrumental characteristic of the case study was more in force. In an instrumental case study, random selection of cases is neither necessary nor preferred. One would rather choose a case where the object of interest is 'transparently observable' and likely to extend the emergent theory (Eisenhardt, 1989). In my case, the faculty members at NMBU had explicitly stated that they wanted to educate teachers who can contribute to sustainable development, and this made this case especially interesting. This overall aim and the lack of similar cases (i.e.

teacher education programs with emphasis on ESD) in Norway (Straume, 2016) made NMBU a good case to select.

Case studies can involve either single or multiple cases (Eisenhardt, 1989). A multiple-case study is often preferred over a single-case study since the evidence is more compelling and the conclusions are more powerful. However, a single-case could be preferred under some circumstances, such as when the case represents a unique case (Yin, 2009), as in this case. Corcoran, Walker, and Wals (2004), claimed that a case study is the ideal research tool for studying sustainability in higher education due to the flexible and adaptive nature of the methodology, but the study should be documented in such a way that it can have transformative value for others. I have therefore attempted to give rich descriptions of both the context and analysis throughout the extended abstract and the articles.

This research can further be classified as ethnographic. In ethnography, the researcher 'immerses him- or herself in a group for an extended period of time, observing behaviour, listening to what is said in conversation both between others and with the fieldworker, and asking questions' (Bryman, 2012, p. 432). It could also be positioned within autoethnography which is 'an approach to research and writing that seeks to describe and systematically analyze (graphy) personal experience (auto) in order to understand cultural experience (ethno)' (Ellis, Adams, & Bochner, 2011, p. 273). However, since I had no teaching obligations when starting the research and my role in the overall teaching was minor, my personal teaching experience was of little account, and I would rather describe this research as an ethnography in my own context.

I followed the case in three executive years, from 2010 to 2012. My role in these three years can according to Bryman (2012) be classified as an 'overt full member', meaning that I had full membership as a paid employee for the group and that my status as a researcher was known to the other group members. In the following sections, I will extend the research design into data collection and analysis, but I will first present the participants, including both the student teachers and teacher educators, and my role in the context.

4.1.1 Project participants

The study included the 36 student teachers attending the science teacher education program in 2011/12 and the 43 student teachers attending the residential field course at Finse in 2012. The teacher education program is offered both as a full-time study and as a part-time study.

The student teachers in the part-time study attend the same modules as the student teachers studying full-time, but they attend science education modules the first year and the pedagogy modules the second year. I therefore included the part-time student teachers attending year 1 in the study, in addition to the full-time student teachers, as these were the student teachers attending the science education modules.

The teacher education program is offered in science, mathematics and agriculture. The student teachers may attend one of these subjects, or a combination of two of them. The student teachers in the agriculture program has either an academic or a vocational background, while the student teachers in science and/or mathematics has an academic background. Thus, the academic background among the student teachers vary from some student teachers who possess doctoral degrees in a scientific subject or mathematics, to a farmer, perhaps with limited formal education, re-educating to become a teacher.

There is a wide diversity when it comes to the personalities and general background of the student teachers. Some student teachers have years of work experience and some of them have none. They also differ in other ways, based on the previous discussion of identity (see Section 2.1.3). I will, however, argue that the diversity among the student teachers in the teacher education program at NMBU is particularly large due to the distinctiveness of the university. One contributing factor is the diversity in the subjects offered in the teacher education program. Another factor is that many student teachers chose NMBU deliberately due to the University's history and roots in agriculture. Thus, the student teachers are both people with a particular interest in NMBU and its founding values – and at the far opposite end of the scale, people from larger cities who have no experiences within agriculture and perhaps chose to study teacher education at NMBU by chance or because of convenience (e.g. due to the organisation of the teaching modules, etc.).

This diversity leads to a variety in the group of student teachers and there are many positive side effects, as the student teachers contribute with different perspectives through their experiences both from work and personal life. In the teacher education program, group work and plenary discussion is highly included and the learners are affected by the experiences both lecturers and fellow student teachers bring. Thus, even though I did not include the agriculture students in my analysis, they still contributed to the result through their contributions in discussions, etc. The diversity can also be challenging, for example if student teachers with different backgrounds, worldviews and/or personalities are going to collaborate in a larger project such as the pedagogical development project.

The teacher educators also bring different work experiences and backgrounds into the teacher education program; some teacher educators have been working as teachers and bring knowledge from their teaching practice into the program, while other teacher educators have a more methodological training with emphasis on research. They also have different pedagogical foundations and research interests as described in Section 3.2. Finally, their identities and personal background differ just as much as among the student teachers. Regardless of backgrounds, the teaching staffs in pedagogy and science education work closely together. The overall teacher education program is planned each year in joint meetings, distributing topics to cover in each session. Further, most teaching staff in pedagogy also teach in science education and/or agriculture education.

The teacher educators had different contributions in the project. All teacher educators working in the program during the case study contributed through participation in meetings – and I also observed teaching session involving most teacher educators. In addition, I interviewed the following teacher educators:

- Hans Erik Lefdal because he has been the leader of the teacher education institution from the beginning (1999).
- Solveig Strangstadstuen because she has been working in the teacher education program for several decades, including before it was terminated in 1990.
- Astrid Sinnes because she was the leader of the LUR-program and seemed to have been strongly involved in ESD becoming a focus in the teacher education program.
- Edvin Østergaard about phenomenology and phenomenon-based teaching in order to achieve a better understanding of the phenomenological approach at NMBU.
- Guðrún Jónsdóttir, Knut Omholt, Sigrid Gjøtterud and Solveig Strangstadstuen in a focus-group conversation to get an understanding of the realisation of ESD in the pedagogy modules.

I have also been working in the teacher education program myself during the years of the project. In the academic year 2011/2012, my main contribution in the teacher education program was linked to supervising student teachers. I supervised four student teachers in their practical training and on their individual assignments, and one group of student teachers on their pedagogical development project. I also visited a group of student teachers in Malawi where they had their practical training. I contributed in a couple of teaching sessions as well: one session on chemistry in an outdoor context at Finse and one session on chemistry learning later that fall. I also supervised student teachers in their teaching sessions at Finse and I was responsible for the practical arrangements around the residential field course.

In the academic year 2012/2013, my only contribution to teaching was co-hosting the teaching session on chemistry and biology in Finsevannet. I was responsible for the practical arrangements around the residential field course this year as well.

I have, as described earlier, my educational background from NMBU. I attended the LUR program from its beginning in 2004 and I knew some of the teacher educators before the project started. My role could therefore, according to Corcoran et al. (2004), be considered an insider. However, the LUR program developed greatly during the first years and the teaching was quite different for my class compared to how it was when I started the case study. Thus, even though the program built on the same pedagogical principles, I still felt like an outside evaluator (Corcoran et al., 2004). It was also quite different to go from the role of a student teacher to a colleague, which enhanced the feeling of outside evaluation.

I decided on a project at the end of 2009, and was participating in meetings related to the teaching and the development of SLL from January 2010. I participated primarily as a researcher, but also as a participant. This changed with time as I became more of an ‘equal’ participant (in my point of view), and I got more involved in the meetings during the spring of 2010. I have attempted to be transparent in my role in the teacher education program, both in the written work and when communicating with the participants.

4.2 Data collection

The focus of the research shifted throughout the case study. In the first years of the project, my aim was to contribute to the reorientation of the teacher education program towards ESD, and my initial research strategy therefore adopted an action research approach. Before I started my PhD, the teacher educators at NMBU had already decided to have ESD as the main focus of the teacher education programs, making it a valuable starting point for an action research project, since the desire originated from the practitioners themselves (Reason & Bradbury, 2008). However, even though the basis of the project was in line with an action research approach, I saw the need to analyse the existing ESD realisation. This is in accordance with Van Petegem et al. (2007), who suggested that a good way of improving the ESD realisation is to make an inventory of all existing initiatives in order to reveal gaps that could be filled by new items. I therefore chose to follow the teacher education program as a regular case study instead. By moving away from an action research approach, the focus on developing the existing practice was reduced, but the benefit was that it gave me the time and opportunity to achieve a deeper understanding of the ESD expression in the existing teaching.

Although this ended up not being an action research project, the action research approach followed in the beginning of the project has affected the outcome of the project. Several meetings have been held with this aim in mind, and the fact that it once was an action research project has most likely influenced the mentality of the faculty staff. When this is said, I will not and cannot take the credit for the ESD development at SLL; the aim was already stated and the people were already working with this aim in mind. I will, however, claim that the action research project and the case study has contributed to further development of the ESD realisation in the teacher education program and has improved the growing conditions for the seed that was already planted.

My ambitious plans at the beginning of the PhD project also included a broader perspective when it came to what I wanted to include as part of the case study. There were, and still are, several ongoing processes and projects at NMBU that can be linked to ESD, and I followed all teaching and research activities relevant for ESD. This included participation at most meetings linked to teaching and research. Based on the documented trouble teachers have with realising ESD and the need for teacher education programs to reorient in order to address sustainability, I chose to narrow my scope arriving at the case structure described earlier. In Article II, I chose to look at the realisation of ESD in the science education program in the academic year 2011/2012 and in Article III, the scope was narrowed down further, analysing one specific module, i.e. the residential field course arranged as a part of the second science education module in the academic year 2012/2013. Article III can thereby be seen as an in-depth study of Article II. I chose to go in-depth on the residential field course because outdoor education is a central element of both the overall ESD aim of the teacher education program (NMBU, 2011) and in the ESD literature (Malone, 2008; Palmer, 1998).

The strength of a case study is the variety of data that can be used (Yin, 2009). However, this variety may lead to a large volume of data and potentially ‘death through data asphyxiation’

(Pettigrew, 1990, p. 281). The broad data collection contributed to an enormous pool of data, despite Pettigrew's warning. However, it also gave me a great understanding of the system and I got a good foundation to build my research upon. A timeline giving an overview of the research activities in my PhD project is given in Figure 8.[16]

Figure 8: Timeline illustrating research activities in the PhD project

The data in this project have come from four different sources: participant observation, direct observation, interviews and documents (instructional artefacts, administrative documents and assignments and feedback from the student teachers). An overview of the total data set according to each source is given in Table 3 below. The data from the academic years under study were core data of the analyses, while data from prior teaching and research activities were used to contextualise the analyses of this core data; the data are labelled accordingly in the table.

[16] The pictures in Figure 8 are from a meeting on ESD in the teacher education program

Table 3: List of data and their status

<table>
<tr><th colspan="2">Source of evidence</th><th>Description of data</th><th>Status of data</th></tr>
<tr><td colspan="2" rowspan="3">Participant observation</td><td>Sound recordings and reports from meetings</td><td>Contextualising data</td></tr>
<tr><td>Researcher’s reflection notes from meetings</td><td>Contextualising data</td></tr>
<tr><td>Researcher’s reflection notes from teaching activities</td><td>Contextualising and core data AII and AIII</td></tr>
<tr><td colspan="2" rowspan="4">Direct observation</td><td>Sound recordings from some teaching sessions</td><td>Contextualising data</td></tr>
<tr><td>Researcher’s reflection notes from teaching activities in 2010/2011</td><td>Contextualising data</td></tr>
<tr><td>Researcher’s reflection notes from teaching activities 2011/2012</td><td>Core data AII</td></tr>
<tr><td>Researcher’s reflection notes from teaching activities at Finse</td><td>Core data AIII</td></tr>
<tr><td colspan="2" rowspan="2">Interviews</td><td>Sound-recordings from four semi-structured interviews with teacher educators about ESD in the teacher education program</td><td>Contextualising data and core data AII</td></tr>
<tr><td>Sound-recordings from a focus group conversation with four PED teachers about ESD in the PED modules</td><td>Core data AII</td></tr>
<tr><td rowspan="11">Documents</td><td rowspan="3">Instructional artefacts</td><td>Schedules for each of the 12 teaching modules in 2011/2012 with information letters describing the modules</td><td>Core data AII</td></tr>
<tr><td>Schedule and information letter for the module at Finse in 2012</td><td>Core data AIII</td></tr>
<tr><td>PowerPoints, assignments and memos from teaching activities</td><td>Core data AII and AIII</td></tr>
<tr><td rowspan="3">Administrative documents</td><td>Application (Centre for Excellence in Education’</td><td>Contextualising data</td></tr>
<tr><td>Report from the external evaluation of the teacher education programs and a self-report written as preparation for the evaluation</td><td>Core data AII</td></tr>
<tr><td>Curricula for the teacher education program (national and local curricula)</td><td>Core data AII</td></tr>
<tr><td rowspan="5">Assignments and feedback from the student teachers</td><td>Student evaluation schemes from 2011/2012</td><td>Contextualising data</td></tr>
<tr><td>Summary of evaluation schemes from Finse, 2012</td><td>Core data AIII</td></tr>
<tr><td>36 science education assignments, where the student teachers chose an issue within science education to discuss, linked to practical training and educational theory</td><td>Core data AII</td></tr>
<tr><td>37 exam preparative assignments, where the student teachers reflected on their development as teachers</td><td>Core data AII and AIII</td></tr>
<tr><td>6 pedagogical development projects, where the student teachers worked in groups in order to improve or to suggest improvements in educational practices.</td><td>Core data AII</td></tr>
</table>

Observation is the primary source of information in ethnographic methodology (Gobo, 2008). I used two types of observation in this project: *participant observation* and *direct observation* (also called *non-participant observation* (Gobo, 2008)), depending on my role in the setting (Yin, 2009). I participated actively as a peer in the meetings at the section, and my observation in these meetings can therefore be labelled participant observation; in participant observation, the researcher is not merely a passive observer. I also contributed in some of the teaching sessions, and I was therefore a participant observer there as well. Otherwise, direct observation was the method I applied for observation. In direct observation, the researcher is a passive observer (Yin, 2009).

Some of the observation was documented by sound recordings. I recorded and transcribed all meetings in 2010 and 2011. I also recorded and transcribed the teaching sessions with an outspoken ESD topic, such as the sessions in Module 1 focusing on renewable energy, ESD and teaching for the future, and the sessions in Module 12 focusing on ESD competencies and examples of ESD from schools. All transcription in the project was done on a lexical level, preserving the meaning as a whole (Lemke, 2012) – since my main interest was the content linked to how ESD was realised. When observing the teaching sessions, I also made reflection notes. The reflection notes were not systematic field notes, but rather recordings of reflections and thoughts to follow up in the analysis.

Interviews constituted a small portion of the data. In the process of defining the case, I originally chose to look at how ESD was realised in the science education modules. I therefore followed the teaching in the science education modules in both 2010/2011 and 2011/2012, and the residential field course at Finse in 2012/2013. However, since the pedagogy and science education modules were closely linked, and the pedagogy modules supplied the ESD expression of the science education modules, the science education modules gave an incomplete picture when analysed alone. I therefore chose to include the pedagogy modules and the other aspects of the teacher education program as well. This change was decided upon after I finished the observation process, and is the reason why I have no observation data from the pedagogy modules. The focus-group conversation was therefore conducted to supplement the documentation and to get a broader understanding of the pedagogy modules, and it was included as core data in the analysis. A benefit of focus-group conversations is that it enables the researcher to gather large amount of information in limited periods of time (Madriz, 2000; Morgan, 1996).

In addition to the focus-group conversation about the pedagogy modules, I interviewed Hans Erik, Solveig and Astrid about the history of the teacher education program, related to the process in which ESD became a focus area and overall goal. These three interviews were primarily used to get a broader understanding of the context and the history of the teacher education program. I also interviewed Edvin about phenomenon-based teaching due to the lack of data from observation and to increase my understanding of phenomenon-based teaching at NMBU. Thus, this latter interview was also included as core data. All interviews were semi-structured and the interview guides are given in Appendix 2-4.

Looking back at the interviews some years later, I will argue that exchanging them with focus group conversations could have been a fruitful approach. In the focus group conversation with the teacher educators in pedagogy, I experienced both similarities and discrepancies in their views on ESD, and more ideas evolved due to group dynamics. This is in line with literature suggesting that focus group interviews can be used to develop emergent ideas, to corroborate stories and to provide a context for participant responses, and thereby add meaning to already shared ideas (Fontana & Frey, 2000; Morgan, 1996). Thus, I would in retrospect rather have used focus group conversations than the four individual interviews.

The reason why I chose to interview Hans Erik, Solveig and Astrid individually was that I wanted to have their personal perspectives on the ESD process, and group culture may interfere with individual expressions when conducting focus group interviews (Fontana & Frey, 2000). However, I see now that the group dynamics could have given even more fruitful results, where both agreements and disagreements could have given new and better insight, since the aim was to bring forward the different viewpoints rather than consensus about the topic (Kvale & Brinkmann, 2009). The same is the case with the interview about phenomenon-based teaching, which I chose to conduct in order to get a brief introduction to the perspective as it was applied at NMBU. A focus group interview with the three involved teacher educators could have given more (i.e. added meaning to the shared ideas), especially with respect to their thoughts on the role of phenomenon-based teaching in ESD.

A final source of data was *documents*. Throughout the project, I had access to the digital learning platform that was used in the teacher education program, with all information given and all assignments handed in by the student teachers. The documents in the project consisted of instructional artefacts from the teacher education program (i.e. PowerPoints and hand-outs), administrative documents (i.e. curricula, applications and evaluations), and evaluation schemes and assignments from the student teachers (science education assignments, exam preparative assignments and pedagogical development projects).[17] 2011/2012 was the only year the exam preparative assignment was written in science education and pedagogy combined (as opposed to pedagogy only). The assignments were therefore richer and more linked to the teaching in the teacher education program than other years. Several student teachers wrote about their experience at Finse and these assignments were included in both Articles II and III. The student teachers writing these assignments had attended the field course in 2010 (part-time students) or 2011, but the assignments were still included in the analysis in Article III, as the student teachers pointed to aspects of the field course that were not related to the specific year.

It would have been beneficial if ESD was a given topic in the assignments analysed, since it could have provided an enhanced impression of the success of the ESD realisation. This is especially related to the auxiliary research question in Article II, addressing how the student teachers in the teacher education program demonstrated their understanding of ESD. The research question was analysed based on two types of assignments where the student teachers (1) reflected on how they had developed as teachers and (2) discussed an issue within science education. Since ESD was not a given topic, the assignments only gave us indications of their understanding of ESD.

The lack of observation data from the pedagogy modules and phenomenon-based teaching is another weakness of the project. I had to rely deeply on documents in these teaching sections. Rubin and Rubin (2011) emphasised that documents are most useful when combined with interviews that allows you to discuss the content. I did not go through such systematic interviews, but I still got an increased understanding of the documents and the respective teaching sessions through participation in meetings discussing these sessions. Interviews may give the researcher insight in the interviewees' experiences and motives (Rubin & Rubin, 2011). Thus, even though interviews can be considered a way of self-reporting, it could have been interesting to interview the teacher educators responsible for other relevant teaching

[17] All documents are described in Table 3.

sessions, in order to explore the sessions from their perspectives. Another interesting move, in hindsight, would be to interview the student teachers showing the most advanced understanding of ESD in order to get their perspectives and advices on the realisation of ESD in the teacher education program.

4.3 Analytical procedures

In this section, I will describe how the data was analysed. Yin (2009) pointed to the difficulty of analysing case studies and stated:

> Too many times, investigators start case studies without having the foggiest notion about how the evidence is to be analyzed (…). Such investigations easily become stalled at the analytical stage (…) not knowing what to do with the evidence. Because of the problem, the experienced case study investigator is likely to have great advantages over the novice at the analytical stage. Unlike statistical analysis, there are few fixed formulas or cookbook recipes to guide the novice. (Yin, 2009, pp. 109-110)

Being a novice case study investigator, I recognise all aspects of Yin's statement. I started my data collection without knowing how I was supposed to analyse the data, and when most data was collected, I invested a lot of time in the search for suitable analytical frameworks and strategies. My original aim was to find an existing model I could use for analysing the case, and I read large amounts of literature on ESD in a search of models, but I ended up using the elliptic ESD model developed in Article I and presented in Section 2.3.1. This choice was explained in Section 2.3.3 and is further discussed in Section 4.4.5.

4.3.1 Analytical strategy

The analytical strategy applied in this thesis was largely inspired by Kvale's *(1996)* concept of *meaning categorisation.* In meaning categorisation, the data material is coded into categories; the categories can be developed in advance or they can arise during the analysis. In my case, the categories were the sub-categories of the elliptic ESD model (with names changed from chemistry- to science education). Any presence of the sub-categories was marked with one out of two different nuances: emphasised or slight emphasis. The category was considered emphasised when it was the focus of a session or when the teacher education program contributed with pedagogical tools in order to facilitate the student teachers' realisation of the category in their teaching. For example, when the student teachers were introduced to and worked with distinct tools for learning collaboration, strategies for dealing with conflicts, the supervision of project work etc. The category was considered to have slight emphasis when the student teachers themselves experienced, for example, collaboration through the teacher education program. In other words, when the topic was focused upon implicitly or the topic was in force as collateral learning (Dewey, 1938). Collateral learning is what one learns through and by doing other things; when the student teachers also learn about a specific topic (e.g. gene testing) when the purpose actually was to practice a specific teaching method (e.g. role play) – or the opposite when the student teachers practice a specific teaching method (e.g. world café) when learning about a topic (e.g. pedagogical learning theories). Thus, each session was analysed using the analytical framework given in Table 4.

Table 4: An overview of the analytical framework

Main category	**Sub-category**	***Emphasised***	***Slight emphasis***
Content knowledge	Content knowledge		
Science in context	Science in context		
Science's distinctiveness and methodological character	Nature of science (NOS)		
	How to work sustainably in science		
ESD competencies	Systems thinking		
	Problem-solving		
	Creativity		
	Critical thinking		
	Action competence		
	Future thinking and belief		
	Normative competence		
	Communication		
	Collaboration		
Lived ESD	Pupil participation		
	Community engagement		
	Learning environment		
	The role of the teacher		
	Sustainable school management/development		

Since the categories were developed both in advance and during the analysis, all empirical material was re-analysed using the final version of the analytical framework. In the beginning, the software ATLAS.ti was used in the coding process. However, I found the software to be too rigid for my data and I ended up doing a more analogue analysis in OneNote, where I wrote a brief narrative of each section and identified which categories being in focus and why. The analytical process is described in detail for each article below.

4.3.2 Data analysis in Article II

The data that underlies Article II was analysed through five distinct stages. Firstly, *the six science education modules* were analysed through a three-step procedure:

- In Step 1, I went through the time schedules in order to exclude the sessions not being relevant for ESD. This selection was made based on my prior knowledge from observation of teaching activities and participation in meetings. One may therefore say that the first step of the analysis occurred already in the process of collecting and selecting data, in accordance with Kvale and Brinkmann (2009). If doubt occurred with respect to the ESD relevance, PowerPoint presentations and memos were conferred. If I was still in doubt whether the session should be excluded or not, I included the session in the analyses.
- In Step 2, all empirical material from one teaching session were studied in order to get a more in depth understanding of the session. In this process, a brief narrative of each session was written. I had various prior knowledge about the different sessions (I had been participating in some of them through observation or maybe even teaching, while I had no knowledge of other sessions, and these had to be analysed based only on power points and hand-outs from the lecturers), and to put it in the words of Erickson (2012, p. 1452), one needs to know what the 'treatment' was before answering what 'the effects of the treatment' were, and such narrative descriptions were therefore necessary. This step can also be linked to Kvale's (1996) concept of *meaning condensation*, where the meaning is expressed in shorter formulations, and it can be considered the second step of the analysis. I analysed in total 30 science education sessions, and an overview of each analysed session with the corresponding narrative is given in Appendix 1.
- In Step 3, the empirical material was revised and analysed using meaning categorisation. Each relevant teaching session was analysed according to Table 4.

In order to illustrate how the meaning categorisation was conducted and related to the two levels, I will exemplify through the analysis of the session called 'teaching for the future' with the following narrative from Appendix 1:

> In a future workshop, the student teachers worked in groups and discussed what they wanted the world to look like in twenty years. They also discussed how science education can support such a development.

The task itself demanded *science in context* since the session connected science education to sustainable development, and *future thinking* since the student teachers had to envisage a future society and future science education. Thus, these two categories were considered emphasised. Another category that was considered emphasised was *the learning environment*. The teaching session was held after lunch at the first day of the program, but the groups were still divided before lunch in order to ensure that all student teachers had someone to eat lunch with at their first day of the study. The group work had, in other words, a dual role – both the assignment in itself and as an activity for the student teachers to get to know each other and to establish a safe and friendly learning environment in the group. *Problem-solving, creativity, collaboration* and *pupil's participation* were categories covered through collateral learning when solving the task that implied student-active methods, and where therefore categorised with slight emphasis. Finally, the *role of the teacher* was implicitly covered since the emphasis was on science education.

In the second stage, *the six modules in pedagogy* were analysed in a similar way as the science education modules. These modules were more holistically composed than the science education modules, and each module was therefore analysed as an entity instead of session by session. Step 1 above was therefore redundant. Furthermore, the modules were analysed based on documentation and the focus-group conversation, since the modules never were observed as discussed before. The documentation included both hand-outs to the student teachers and reports from meetings.

Thirdly, *the general perspectives of the teacher education program* were analysed through meaning categorisation with the same categories in order to cover other aspects of the teacher education program. The general perspective covered activities and aspects that was present throughout the year, across the specific modules. It included the analysis of the administrative documents in Table 3, such as leading document (e.g. the local curriculum, and documents from practical training), and the reports related to the external evaluation of the teacher education programs (i.e. the external evaluation report and the self-report). It also included the analysis of aspects of the modules that were not covered by the analyses of the distinct sessions, such as the social aspects, the learning environment, etc.

At the fourth stage, *the results were summarised*. The ESD expression of each module was summarised in four different nuances (not covered, partly covered, partly emphasised and recurrent emphasis) and an overall interpretation of the realisation of ESD in the teacher education program was done, as illustrated by Table 3 in Article II. There were no fixed boundaries in these nuances, and the summarised ESD expression of each module was evaluated separately.

Finally, *the assignments written by the student teachers* were analysed. All three types of assignment were analysed according to Step 3 above. The emphasis in the analysis was on the inclusion of the categories from the elliptic ESD model. Thus, the student teachers did not necessarily write about ESD, but they had to explicitly discuss elements from the model for it to be included in the analysis. All science education assignments (n = 36) and the exam preparative assignments written by the full-time student teachers (n = 19) were analysed, and the percentage of each sub-category was calculated and visualised in diagrams. The development projects were also analysed, but not included in the findings because of the small number of relevant assignments (n = 6). The exam preparative assignments of the student teachers who attended the science teacher education program in combination with mathematics or agriculture (n=17) were analysed as well, but the results were not included in the diagrams as the teaching modules were somewhat different.

The data were triangulated thereafter. According to Flick (2004), triangulation is observing the research issue from at least two different points. Triangulation can be a tool for coping with large amounts of data and generation of insight through a within-case analysis (Eisenhardt, 1989), but the main purpose is to ensure validity of the research project (Flick, 2004). Literature operates with four types of triangulation: triangulation of data, investigator triangulation, triangulation of theories and methodological triangulation (Flick, 2004; Yin, 2009). In this thesis, I have used two types of data triangulation: I have combined data from different sources in order to corroborate the analysis of each session, and I have triangulated using data from different perspectives in order to corroborate the analysis of the entire teacher education program. The latter way of triangulating may also be called 'systematic triangulation of perspectives' (Flick, 2004). The three perspectives used in the article were: (1) the teacher education program perspective, which included the analyses of the science education modules, the pedagogy modules and the general perspective combined; (2) the teacher educator perspective, which included how the teacher educators talked about ESD in meetings and interviews; and (3) the student perspective, which included the analysis of the assignments and evaluation schemes. Perspectives 1 and 2 were analysed separately and combined as a joint perspective in the process of writing the article. This joint perspective was thereafter compared with the student teacher perspective in the article.

4.3.3 Data analysis in Article III

When analysing the residential field course, I started out writing a narrative presenting the field course using the meaning condensation approach. Thereafter, each session was analysed through meaning categorisation using the categories from the elliptic ESD model and the framework given in Table 4. In this article, I chose to use the sub-categories from the model, but I did not include the model itself in the article, because I found the hierarchy of the model to be redundant in this article. I will further discuss this choice in Section 4.4.5. An example of the analysis is given in the methodology section of the article. The results from the analysis of the field course were corroborated with feedback from the student evaluation and the exam preparative assignments from 2011/2012.

In the next section, I will address the literature review methodology used in Article I.

4.3.4 Literature review methodology and reflections

I used literature review with relevance coverage to develop the elliptic ESD model. In order to identify the relevant literature, I established several criteria for guiding the selection of studies to build upon. I sought literature that (1) focused on ESD or EE, (2) in secondary schools, and (3) within chemistry education or science education. Much of the literature within ESD consists of political documents. Political documents provide regulations and express political intentions, and in the work with the model, I therefore tried to keep to research literature instead, as research reports reflect more fully the actual state of education.

Procedurally, I systematically searched the literature using the following key words: chemistry education, science education, chemical literacy, scientific literacy, ESD, competencies, sustainability and environmental education. The search on chemical literacy gave especially useful results. When relevant literature was found, I examined the references in order to achieve a deeper understanding. When the skeleton of the framework had been established, a more specific search was done within each element, e.g. within specific competencies. During the final stage of the model development, I benefited greatly from the review process in the journal where the reviewers made thoughtful comments and provided useful suggestions for further literature.

In order to develop the model, I started out from the four strategies for implementing issues of sustainable development in formal chemistry education presented by Burmeister et al. (2012). This work was modified and expanded through an education through science perspective

(Holbrook, 2005), where I also drew on research literature from the fields of scientific literacy (Aikenhead et al., 2011; Bybee, 1997; Roberts, 2011) and SSIs, in addition to ESD.

Much effort was involved in developing a decent list of ESD competencies and their content. The question leading this work was ‘which competencies will chemistry learners in secondary schools need in order to support both present and future actions for sustainable development?’ Even though several lists of competencies had been developed in the sustainability literature (de Haan, 2010; Voogt & Roblin, 2012; Wiek et al., 2011), I did not perceive any of them as being directly suitable for my model. However, I was inspired by the concept of *Gestaltungskompetenz* (de Haan, 2006, 2010) and the 21st-century competencies presented by Voogt and Roblin (2012) when the list of competencies was developed. Even though the 21st-century competencies were developed with another purpose than ESD in mind, I found them to be relevant for ESD due to the focus on competencies for an unknown future (Jegstad & Sinnes, 2015). This is also in line with literature arguing that ESD aims to help learners ‘respond to the complex socio-ecological issues of the 21st century’ (Evans et al., 2017, p. 406).

The model is deeply founded in theory, but the teaching in the teacher education program and the analysis of the empirical material also inspired the work and contributed to the development of the model. Hence, an abductive approach with a dialectic relationship between the theory and data (Svennevig, 2001) was used and the model was inspired by the pedagogical principles that the teacher education program builds upon, related to the teacher educators’ understanding of ESD. The teaching in the teacher education program was already focused on aspects within the different ESD categories. However, the wording was not necessarily the same and the content of the ESD categories was not set either. I therefore named the five categories, and through the work with the theory and analysis of the empirical material, the categories and sub-categories were further developed and became more explicitly apparent.

4.4 Reflections on the project and its trustworthiness

Case studies conducted by the practitioners themselves can be valuable in improving the practices, but it also has the disadvantage of not providing critical external feedback (Corcoran et al., 2004). It is therefore important to be transparent in the working methods to make the study trustworthy. Robson (2002) put forward three criteria involved in trustworthiness: reliability, validity and generalisability. *Reliability* says something about whether the same results would have been attained if the research was repeated (Kvale & Brinkmann, 2009; Robson, 2002). *Validity* is, as put in Robson's words, 'whether the findings are "really" about what they appear to be about' (Robson, 2002, p. 93). Finally, *generalisability* refers to what extent the findings are generally applicable for other cases (Robson, 2002). In this section, I will reflect on these three criteria with respect to my project. Thereafter, I will reflect on the ethical aspects of the research project and, finally, limitations of the study.

4.4.1 Reliability

Reliability in qualitative research can be strengthened by thorough documentation of the research procedures (Kirk & Miller, 1986) and being systematic and rigorous when conducting the research (Moisander & Valtonen, 2006). Yin (2009) argues that '[t]he general way of approaching the reliability problem is to make as many steps as operational as possible and to conduct research as if someone were always looking over your shoulder' (p.45). To secure reliability and minimise the errors and biases in my project, I have therefore been thorough and explicit in the steps of the analyses and I have kept a case study protocol (Yin, 2009) where I have explained the analyses of each teaching module. In order to be systematic and rigorous in the research process, I have gone through the schedules for the modules several times in order to make sure that all sessions/aspects relevant for ESD were identified and each session/aspect has further been analysed at least twice. I have also attempted to be transparent in the research design.

I have been doing research in my own context, which has been both beneficial and demanding. Getting access to the field is crucial in qualitative research (Denzin & Lincoln, 2000) and doing fieldwork in your own organisation could therefore be considered easy because one knows the language and often has assumptions etc. in common with the people being studied. When I started my project, the teacher educators at NMBU were just about to finish an action research project on student guidance (Gjøtterud, 2011). The teacher educators were therefore used to being involved in research processes in their own practice and I found it easy to get access.

Wadel (1991) argues, on the other hand, that studying one's own culture in many ways is found more difficult than studying a strange culture because so many things in one's own culture is taken for granted. It is easy to miss out on critical questions that could have given new perspectives. To reduce the risk of taking perspectives of the ESD realisation for granted, I have rather analysed too many sessions than too few; if I was in doubt whether a session was relevant for ESD or not, I chose to include it in the analysis in an attempt to not miss something relevant.

4.4.2 Validity

Validity is about testing 'whether a method investigates what it purports to investigate' (Kvale & Brinkmann, 2009, p. 327) and whether the findings are correctly interpreted (Kirk & Miller, 1986). In other words, it refers to 'how true the claims made in the study are or how accurate the interpretations are' (Moisander & Valtonen, 2006, p. 24). In order to construct validity of a case study, Yin (2009) suggests to use multiple sources of evidence, establish chains of evidence and have key informants review draft case study reports. *Triangulation* is a common validation strategy in qualitative research, and both data triangulation and perspective triangulation was used in this study, as described in Section 4.3. *Respondent validation* has also been in force, due to the collaboration with my supervisors. I have been conducting the analysis, which they have commented on. In this process, I always got feedback linked to my interpretation of the data as well. The feedback was founded in their knowledge and experiences as teaching staff in the case analysed. I have also presented my research in conferences and research seminars. However, the people in these seminars have not been a part of the project and have therefore not had an extensive insight in the data material. It would, hence, have been beneficial to be a part of a research group as well. In such a group, the analysis could have been discussed more thoroughly with other scholars with insight in the material.

I have also attempted to view the data from different perspectives myself. I would in this respect argue that my role as an insider in the teacher education program has enhanced my ability to view the data from different perspectives. I have earlier described the different backgrounds of the teacher educators at NMBU and they also have quite different understandings of ESD. When I came into the project, I had my understanding of ESD, which was quite instrumental (Jickling & Wals, 2008) and founded in a fact-based tradition. During the project, I have been working with different people within the context of the teacher education program, and this has given me new perspectives on ESD and an increased appreciation of the importance of diversity within ESD. Thus, I have not only developed personally, but also methodologically, being able to see the data material from more perspectives and conducting a broader and more correct analysis. This is in line with an *abductive reasoning*, where 'the researcher grounds a theoretical understanding of the context and people he or she is studying in the language, meanings, and perspectives that form their worldview' (Bryman, 2012, p. 401). Hence, through my research in the context of this particular teacher education program with a sociocultural perspective on learning, emphasising a social community and collaboration, I have adapted a similar view of learning and ESD, and it has affected how I have worked with the data and what I have seen.

Bryman (2012) warns that doing ethnography as a full member of the group carries the risk of 'going native'.

> Going native refers to a plight that is supposed sometimes to afflict ethnographers when they lose their sense of being a researcher and become wrapped up in the worldview of the people they are studying. (…) Going native is a potential problem for several reasons but especially because the ethnographer can lose sight of his or her position as a researcher and therefore find it difficult to develop a social scientific angle on the collection and analysis of data. (Bryman, 2012, p. 445)

Even though I recognise the risk of going native, I do not feel that it was a major risk in my research, since my role as a teacher was marginal and I mainly participated in the context as a researcher.

4.4.3 Generalisability

Ercikan and Roth (2006) referred to generalisability as the extent which the findings from one case is applicable to another case. Generalisability is a controversial issue within qualitative research (Gobo, 2008). A common misunderstanding is that one cannot generalise on the basis of a single case. Flyvbjerg (2011) disagreed and came up with the following correction:

> One can often generalize on the basis of a single case, and the case study may be central to scientific development via generalization as supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas 'the force of example' and transferability are underestimated. (p. 305)

The claim that one cannot generalise on the basis of a single case is probably founded in a tradition of statistical generalisation, rather than of analytical generalisation:

> *Statistical generalization* is formal and explicit: It is based on representative subjects selected at random from a population. . . . *Analytical generalization* involves a reasoned judgement about the extent to which the findings of one study can be used as a guide to what might occur in another situation. It is based on an analysis of the similarities and differences of the two situations. (Kvale & Brinkmann, 2009, p. 262, original emphasis)

The findings of this thesis cannot be considered to be statistically generalizable, but they can be seen as analytically generalizable. I have previously pointed to the instrumental characteristic of this case study and the potential the case provides in terms of theory building. This particular case was chosen because of the overall aim of educating for ESD, and such a strategic choice of the case studied maximises the potential of information from single cases (Flyvbjerg, 2011). Thus, even though other teacher education programs must find a way to realise ESD that is suitable for their context, they can still learn from the case studied in this thesis.

Within analytical generalisation, Kvale and Brinkmann (2009) further distinguished between researcher-based and reader-based generalisation. In the former, the researcher provides information about generalisability, while in the latter, the reader judges whether the findings may be generalised. The generalisation in this thesis is mainly reader-based and it has therefore been important to give rich contextual descriptions in order to allow the reader to generalise the findings to other contexts. Thus, through inviting readers to make connections between this study and their own understanding and personal experience, the findings may be transferable (Moisander & Valtonen, 2006).

4.4.4 Reflections on research ethics

Research ethics refer to 'individual and communal codes of behaviour based on a set of principles for conducting research' (Shrader-Frechette, 1994, p. 2), and a researcher has the responsibility of doing *good* science. Christians (2000) presented four guidelines in order to summarise the academic code of ethics.

The first guideline involves *informed consent* and that all research subjects have the right to be informed about the project they are involved in. Early in my project, I applied to Norwegian Social Science Data Service (NSD) in order to do research at NMBU. NSD is a resource centre that assists researchers with issues of methodology, privacy and research ethics (NSD, 2011). NSD is also the data protection official for research for the Norwegian universities. Since the emphasis in my research was on the teacher educators with respect to how they realised ESD in their teaching, consent forms were collected from the teacher educators only, and not the student teachers. The student teachers were aware of my project, but since I followed several years with 80 – 100 student teachers involved each year, I did not collect formal approval from the student teachers. This decision was made in collaboration with a counsellor from NSD. We agreed that the student teachers only had a secondary role in this project, and the primary research objects were the lecturers because the emphasis was on the realisation of ESD in the teacher education program. I have, however, collected approval of student teachers who were recorded at tape. The lecturers were informed about the project and that they could withdraw from the project at any time. This information was given both orally and in a written consent form, which they signed.

The second guideline, which is *deception* and that the researcher should avoid deceiving the participants during the research has not been relevant in this project. I did the final analyses long after I quitted working in the teacher education program, and there was no way I could deceive them. I did not interact enough with them and their teaching during the project either to achieve any deception.

The third guideline, *privacy and confidentiality*, has on the other hand been addressed. Christians (2000) points to how 'watertight confidentiality has proved to be impossible' since 'pseudonyms and disguised locations often are recognized by insiders'. This has also been the case in my work and I have chosen to not anonymise the university in the extended abstract. With only eight universities in Norway, and NMBU being the only university educating teachers in agriculture,[18] an anonymization of the university would not have had any effect. Further, my name can easily be connected to the university and the anonymization would not have been real. The teacher educators are not anonymised either due to the same reason. I have, however, anonymised the university in the articles due to the process of peer-reviewing. Another reason to not anonymise the university is to give credit to the people involved in the project. The student teachers are not easily recognised through the data and they have therefore been anonymised and the names used in the articles are pseudonyms. I have also deleted all sound recordings after the conduction of the project. No sensitive data has been collected.

The fourth guideline, *accuracy*, was taken care of through the perspectives addressed in the previous sections. However, I would in hindsight have been more careful when working out the research design in order to get even better data, as discussed earlier.

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[18] Agriculture is offered at other Universities as well, but as a part of the vocational teacher education program. NMBU is the only University offering agriculture as a separate specialisation.

A challenge of doing research in your own organisation is that participants may not agree with your interpretation (Zeni, 1998). I had some experience of this challenge through the respondent validation conducted of my supervisors, who also have been second- and third authors on the articles. They have been working in the teacher education program for more than a decade and have contributed strongly in the development of the ESD expression. Their ownership has therefore been quite evident, and I felt that they had some expectations on behalf of the analysis. When disagreements in the interpretations occurred, they were usually caused by unclear wording or aspects in which one of us had not been aware of or reflected on, and we ended up agreeing. I have, however, been careful if reanalysing, being aware of their ownership with the material and I have tried to be loyal to the analytical framework and procedures.

4.4.5 Limitations of the study

There are some limitations to this study, and I have already addressed limitations related to observation. One limitation is that the study was conducted in the time period 2010–2012, and some aspects of the realisation have changed over the course of time. The pedagogical principles are still the same, but some development is expected and also desired. There has also been a replacement of some teacher educators, which may lead to the introduction of new competencies and areas of interest that have not been analysed in this study.

Another limitation is linked to using the elliptic ESD model originally developed with secondary schools in mind as an analytical framework in a teacher education program. In Section 2.3.3, I elaborated on reasons for using this model rather than other frameworks developed for ESD in teacher education programs (such as the CSCT and UNECE frameworks). One reason is related to the comprehensive nature of the elliptic ESD model, which allows it to reveal a broad range of ESD-initiatives within all the four categories, education *about*, *for*, *in* and *as* sustainable development. It is also developed in an education through science perspective and can therefore be used to analyse ESD realisation even when ESD is not the given topic of the session. Finally, it is developed with the current school system in mind, and it is thereby closer to the field of praxis.

The benefit of using a model developed for secondary schools when analysing a teacher education program was that it revealed directly whether the teacher education program worked with elements important for facilitating ESD realisation in schools – and what aspects that were lacking. Even though the model was developed for schools and the sub-categories had specific meanings in that context, their meanings were expanded in the context of the teacher education program. Other models such as the CSCT and UNECE frameworks informed this expansion. The categories of the CSCT framework do all fit into the elliptic ESD model, as illustrated in Table 2 in Section 2.3.3, and were naturally included in the analysis. The same accounts for the overall categories of the UNECE framework (know, able to do, live and work with others and be). In hindsight, we could have paid more attention to the networking aspect of the CSCT framework in the analysis (our main emphasis was on teaching) in order to reveal issues related to networking with partners in and out of school. We could have also have included some of the more outspoken sustainability perspectives that the UNECE framework provides such as 'the importance of the preparedness for the unforeseen and a precautionary approach' (UNECE, 2011, p. 14).

We did, however, encounter some challenges due to the nature of the model (i.e. it was developed for secondary schools), and the analytical framework could have been improved for analysing teacher education programs. During the analysis, I found the realisation of the sub-categories to be a good measure, but there were some challenges with respect to differentiating in what way the sub-categories were realised. I therefore ended up doing the analysis in two separate dimensions: (1) whether the category was present and (2) to what extent it was present. In the second dimension, I differentiated on the levels of realisation, i.e. whether the category was *emphasised* or had *slight emphasis* as described earlier. These levels worked satisfactorily, but the results became a bit vague. In Article II, we pointed to the dual focus in the analysis of the ESD competencies: how the student teachers were aware of and developed their own ESD competencies – and how the student teachers learned to facilitate the development of ESD competencies among their future pupils. This dual focus is not only related to the ESD competencies, but also to the other sub-categories; the student teachers need to both learn about for example NOS and how to address NOS in future teaching.

In Table 5, I have therefore proposed an updated framework addressing whether the focus is on the development of the student teacher or their teaching competencies.[19] If the focus is on

[19] The word *competency* is in this case related to the student teacher's general teaching competency including all categories of the model and not only ESD competencies.

the student teachers, the realisation can follow the same differentiation as used in this thesis (emphasised or slight emphasis). However, if the focus is on their teaching competencies, a better differentiation can be between theoretical inputs and exemplary teaching. In the first, theoretical inputs can be given on how to facilitate a sub-category among learners. In the latter, the student teachers may experience relevant working methods themselves as learners (through exemplary teaching). There will in some cases be an overlap between the two foci, and I will in those cases suggest to conduct the analysis for both foci.

Table 5: A proposed new analytical framework developed from Table 4

Main category	**Sub-category**	***Focus on development of the student teachers***		***Focus on development of the student teachers' teaching competencies***	
		Emphasised	*Slight emphasis*	*Theoretical input*	*Exemplary teaching*
Content knowledge	Content knowledge				
Science in context	Science in context				
Science's distinctiveness and methodological character	Nature of science (NOS)				
	How to work sustainably in science				
ESD competencies	Systems thinking				
	Problem-solving				
	Creativity				
	Critical thinking				
	Action competence				
	Future thinking and belief				
	Normative competence				
	Communication				
	Collaboration				
Lived ESD	Pupil participation				
	Community engagement				
	Learning environment				
	The role of the teacher				
	Sustainable school management/development				

I have earlier pointed to how we used the entire model as a framework in Article II, while we in Article III used the categories of the model, only, without taking their levels into consideration. In hindsight, this could have been done in Article II as well, since specific attention was not put on the level of the categories and the levels did not contribute with anything extra in the analysis. Thus, I will argue that the levels of the categories are more important when the model is used as a tool for planning ESD than as a tool for analysing ESD, and Table 5 is developed with this aspect in mind.

There are also some limitations with respect to using a model I developed myself, which could be looked upon as a case of leaving the fox to watch the henhouse. However, with an abductive approach to the theory development, this was inevitable. Dubois and Gadde (2002) emphasised the positive aspects of the abductive approach and argued that ‘the researcher, by constantly going “back and forth” from one type of research activity to another and between empirical observations and theory is able to expand his understanding of both theory and empirical phenomena’ (p. 555).

5 Summary of the articles

In this chapter, I will provide a summary of the three articles that are included in the thesis as a foundation and preparation for the general discussion in Chapter 6.

The three articles are written with one or both of my supervisors as co-authors. In Article I, the elliptic ESD model was a result of collaboration between Astrid and me; I provided the main elements of the model and wrote the first draft of the article, while Astrid contributed to the discussion and visualisation of the model. Astrid both reviewed and provided inputs for the drafts. She also contributed by writing some passages of the article. Since the model was developed through an abductive approach, with an interplay between theory and the empirical context, both Astrid and other colleagues contributed with ideas through meetings and teaching sessions, and thereby contributed to the content. In Articles II and III, both Astrid and Sigrid were co-authors. In the initial phase of the writing, they reviewed and provided input on both the written drafts and strategies of analysis. They also commented on the actual analysis and suggested further interpretations of the results. In the final phase of the writing, they commented on the drafts and thereby contributed to the substance of the articles.

5.1 Article I

Jegstad, K. M. & Sinnes, A. T. (2015). Chemistry teaching for the future – A model for secondary chemistry education for sustainable development. *International Journal of Science Education, 37(4), 655-683*

In this article, a model of how ESD can be realised in chemistry education was derived and presented, answering the research question:

- How can secondary school chemistry education be an arena for ESD?

The ESD model (earlier referred to as the elliptic ESD model) was developed as a response to the problems teachers have in order to realise ESD. Thus, through the model we aimed to support chemistry teachers in their educational planning in order to introduce ESD as an integrated perspective across the content of the already existing subject, i.e. in an education through science perspective (Holbrook, 2005). The model contributes with a holistic approach to ESD through chemistry education, and visualises that ESD can be realised in a chemistry education, even when sustainability is not specifically taught as content. We drew on research literature from the fields of scientific literacy (Aikenhead et al., 2011; Bybee, 1997; Roberts, 2011) and SSIs (Hodson, 2008; Kolstø, 2001), in addition to ESD (Burmeister et al., 2012).

The model can be used both as a tool for planning ESD and as a tool for analysing the realisation of ESD. The five categories of the model, chemical content knowledge, chemistry in context, the distinctiveness and methodological character of chemistry, ESD competencies and lived ESD, were visualised as five ellipses in order to visualise the hierarchy of the categories.

5.2 Article II

Jegstad, K. M., Sinnes, A. T. & Gjøtterud, S. M. (in press). Science teacher education for sustainable development: From intensions to realisation. *NorDiNa.*

Article II is the main empirical contribution of this thesis, and the purpose of the study was to investigate how a teacher education institution with the overall aim of educating teachers who can contribute to sustainable development include such practices in its science teacher education program. The research question explored was:

- How can ESD be realised in science teacher education?

In order to answer this research question, we had the following two auxiliary research questions:

- How is ESD realised in an ESD-oriented science teacher education program?
- How do the student teachers in the teacher education program demonstrate their understanding of ESD?

Data was collected through participant observation, interviews and a focus group conversation. All data, which also included instructional artefacts and student assignments were analysed using meaning categorisation (Kvale, 1996) using the elliptic ESD model developed in Article I.

The teacher education program at NMBU operationalised ESD through a strength approach (Hopkins & McKeown, 2002) and hence built on elements already present in the teacher education program in the development of the ESD expression. The analyses showed a recurrent emphasis on lived ESD, science in context and the ESD competencies of problem-solving, action competence, normative competence, communication and collaboration. Thus, we found that an emphasis on sociocultural learning theories and experiential learning gave a solid foundation for ESD. The sociocultural learning theories contributed to the social aspect of ESD through the university culture of the teacher education institution that mirrors the school culture of a sustainable school with particular focus on collaboration and the learning environment. Further, through a focus on experiential learning, teaching approaches such as context-based teaching, outdoor education, phenomenon-based teaching and inquiry learning were included, enhancing the emphasis on pupil participation and science in context.

The student teachers also discussed topics that were related to pupil participation and science in context, mainly through a focus on phenomenon-based teaching or inquiry learning. They emphasised lived ESD and ESD competencies such as collaboration, normative competence, communication. However, the analyses revealed discrepancies in how the student teachers understood the ESD expression and several student teachers found it to not be holistically realised.

Through the analysis of the teacher education program, we found many possibilities for ESD as long as the teaching is made explicit; one cannot expect the student teachers to understand the realisation without guidance.

5.3 *Article III*

Jegstad, K. M., Gjøtterud, S. M. & Sinnes, A. T. (2017). Science teacher education for sustainable development: A case study of a residential field course in a Norwegian pre-service teacher education program. *Journal of Adventure Education and Outdoor Learning*.

This article gives a specific and detailed example of how ESD can be promoted through a residential field course. Residential field courses are quite common in the Norwegian schools, but not in teacher education institutions. At NMBU, the field course is included as a part of the emphasis on exemplary teaching. The student teachers are supposed to feel the teaching experiences ‘on their body’. Hence, in Article III, we analysed one of the teaching modules in depth and the following research question was posed:

- How does an ESD-oriented science teacher education program realise different approaches to ESD through a residential field course?

In order to address this research questions, I collected data through direct observation and participant observation. The data, which also included instructional artefacts, evaluation schemes and assignments written by the student teachers was analysed using meaning categorisation (Kvale, 1996) with the sub-categories from Article I.

Through the field course, the student teachers got experience in outdoor education and spotting subject issues in nature. They also got inspiration and ideas from each other and several of the student teachers expressed intentions of further inclusion of outdoor education in future teaching.

Parts of the field course were devoted to the role of the teacher and the student teachers guided each other, with specific emphasis on how different kinds of feedback may start reflective processes among the learner receiving the feedback. The residential field course also provided the student teachers experience in stepping into something unknown. For some of the student teachers with immigrant background, the whole mountain experience and cabin-life was unknown. However, most student teachers stepped into something unknown through the outdoor education experience and the student teachers used phrases such as ‘the field course was overwhelming but good’, ‘we were thrown into assignments’ and ‘being out of one’s comfort zone’. We have also seen the potential of inquiry learning with respect to realisation of ESD (Burmeister et al., 2012).

In the evaluation schemes, the student teachers pointed to several positive aspects of the field course, such as experience in outdoor education, creativity linked to the potential of outdoor education, collaboration with peers and the social aspect. However, the evaluation schemes also showed, in accordance with the findings in Article II, that the teaching was not explicit enough for all student teachers to reveal the whole ESD-expression.

6 Discussion

Teacher education has been seen as the key to sustainable development, due to the crucial role teachers have in societal change:

> Teachers influence the lives of children who are fortunate enough to go to school. The cumulative effects this daily contact has on the lives of pupils – either as children or later as adults – is enormous. . . . Although teachers are often unsung heroes in our communities, they are our hope for creating more sustainable societies. (McKeown & Hopkins, 2002, p. 252)

However, as I pointed to in Chapter 2, several studies indicate that pre-service teachers, teachers and teacher educators struggle to realise ESD in their teaching (Burmeister & Eilks, 2013; Burmeister et al., 2013; Ferreira & Ryan, 2013; Sinnes & Jegstad, 2011). Furthermore, there seems to be a lack of critically reflected and evaluated empirical research on ESD in teacher education (Evans et al., 2017; Ferreira et al., 2014). Thus, through a study of a science teacher education program focusing on educating teachers who can contribute to sustainable development, this thesis aims *to develop knowledge on how ESD can be realised in the education of science teachers*.

In this chapter, I will first discuss the role of models for ESD realisation. This discussion is related to research questions A and B, referring to how ESD can be realised in chemistry education and science teacher education. I will thereafter discuss some main issues based on the empirical findings from the articles, related to research questions B and C. Finally, I will suggest some guidelines for ESD in teacher education based on the overall results from this thesis.

6.1 The role of models for ESD realisation in schools and teacher education programs

Corcoran et al. (2004) stressed that every school or institution is different, and one should therefore not look for universal ESD models, but rather consider how the practice in one institution can be relevant for another institution.

> Sustainability as a concept takes shape and meaning by the active involvement of all relevant actors in a transparent and highly reflective process that is firmly rooted in the social realities of a given context, but sensitive to emergent realities in other contexts as well. (Corcoran et al., 2004, p. 9)

Though I concede that there are no universal ESD models and that such models would need to be adapted to the relevant context, I still believe that ESD models can be useful. Especially due to the gap between literature and the field of praxis, as pointed to in Section 2.3.

Gilbert and Osborne (1980) described the use of models in science education and pointed to how models enable 'a simplified version of a phenomenon to be produced and therefore concentrate attention on specific features of that phenomenon' (p. 6). Although this quote is from a paper written with scientific models in mind, parallels can be drawn to the elliptic ESD model developed in Article I, where the phenomenon is ESD and the specific features are the five ESD categories, including sub-categories. Any model, either it describes a particular scientific phenomenon or education, is a simplification of reality, but a simplification may be what teachers need when realising ESD.

Palmer (1998) focused on two levels in which formal education can change in order to help EE realise its maximum potential, i.e. at a radical level and at a conservative level. At the radical level, there is a call for rethinking the paradigms and approaches to both education in general and especially ESD. The more conservative level identified by Palmer (1998) focuses on small steps that can be taken to change or modify the existing education. Although I concede with Palmer's radical approach to ESD, I still believe that the conservative level is a more realistic way to modify the existing education. If major changes are suggested, many teachers may disregard the suggestions rather than including them. If the suggestions, on the other hand, are doable within the frames of the system, it is more likely that the teacher will see possibilities for including the suggestions and it would still be a step in the 'right' direction. Thus, by emphasising the conservative level, it is easier to see the possibilities that lie in the school system, instead of the challenges. This is in line with Cotton et al. (2009), who emphasised *evolution* rather than *revolution*.

The elliptic ESD model was developed to support conservative rather than radical changes and evolution rather than revolution, and is adapted to the current Western school system. It can, hence, serve teachers who have problems in terms of realising ESD, and function as a structure to build on and guide their thinking. In other words, it gives an example of how secondary school chemistry education can be an arena for ESD.

Even though the model was developed in chemistry, the nature of the model makes it applicable for science education as well, simply through changing the specific names of the subject, as we did from chemistry education in Article I, to science education in Articles II and III. This slightly alters the content and priority of the sub-categories within the ellipses, but the categories and sub-categories still stand. *Chemical content knowledge* and *chemistry in context* can be directly changed to other scientific subjects, with self-evident changes in content. The change in content also applies to the category *chemistry's distinctiveness and methodological character*, since there are differences in the distinctiveness and methodological character among the natural sciences. For example, there are differences between chemistry and biology with respect to working sustainably in the field. In chemistry, the main emphasis regarding environmental concerns would be linked to green chemistry and the ethical aspects of research. Parallel to green chemistry, biologists emphasise direct damage to nature, such as the removal of organisms in vulnerable areas. The ethical aspects might, however, be even more complex in biology because human beings are sometimes involved as research subjects. Furthermore, biologists need to be aware of indirect threats such as biodiversity, gene testing, gene modification and resistant micro-organisms.

With respect to the category *ESD competencies*, the model should not differ greatly among the natural sciences; the competencies are the same, but the priority of the competencies differs slightly. Problem-solving might, for example, be a more distinct element in chemistry education than in biology education, based on the nature of the subjects. Finally, *lived ESD* is a general category that would not be affected by the change of subject.

Even though the model was developed based on an exhaustive literature review, it still needs to be adapted to the context of the educator. This is in line with UNESCO (2005a) arguing that initiatives from one place need to be adapted to become relevant and appropriate in another place. The model also needs to be further developed along with the progress in research in the field of ESD, and the needs of the current society.

With respect to realising ESD in teacher education programs, McKeown and Hopkins (2002) argued that a *strengths approach* was a realistic tool; many topics and pedagogical strategies relevant for ESD are already a part of the curricula and current teaching, and the key to move forward is to recognise these: 'Begin by ensuring that teacher educators understand the principles of sustainability. Once they understand the concept of sustainability, each teacher educator examines her/his own courses and academic responsibilities for existing contributions to [ESD]' (p.260). In Article II, we found that a strengths approach had been applied in the teacher education program under study, consciously or not. The ESD expression was founded in the pedagogical principles the teacher education program was built upon, and informed by previous and current research projects in the teacher education institution, as described in Section 3.2.1.

A strengths approach can be applied in schools, as well (McKeown et al., 2002). In both cases, the elliptic ESD model can be used as a tool for analysing – and hence revealing – the ESD potential of the existing teaching and curricula. This would allow the educators to include a more systematic, explicit and thorough realisation of ESD. By getting a tool for analysing practice, teachers and teacher educators will get precise concepts to use in discussions and reflections. Such an analysis is in line with the suggestion of making an inventory of all existing initiatives in order to reveal gaps that could be filled by new items (Van Petegem et al., 2007).

Article II in this thesis provides an overview of how ESD *was* realised in the science teacher education program under study and can, together with Appendix 1, be looked upon as an inventory list of this particular teacher education program. It can also serve as an example of how ESD *can* be realised in teacher education programs. However, findings from Article II also pointed to the importance of the teacher educators being aware of the ESD potential in their own teaching sessions, especially when a strengths approach is used, as the expression comes out from existing teaching sessions and might be an implicit part of the teaching.

When the elliptic ESD model is used in the analysis of teacher education programs, it needs to take into consideration both the development of the student teachers and their teaching competencies, as discussed in Section 4.4.5.

6.2 Main findings on ESD in science teacher education

In this section, I will discuss the main empirical findings related to education *for*, *in* and *as* sustainable development, which has been a recurrent division throughout this thesis. The empirical findings of this thesis identified a particular emphasis on education *as* and *in* sustainable development in the teacher education program under study, and these aspects will, therefore, be prevalent in the discussion. We found in Article II that education *about* sustainable development was not emphasised in the teacher education program under study, due to the student teachers' scientific background (they all possessed a science degree). It will, hence, not be discussed separately.

6.2.1 Education as sustainable development and exemplary teaching

A finding that stood out as particularly noticeable in both Articles II and III, and that resonates with the literature studied by Evans et al. (2017), was that the teacher educators under study aimed at being exemplary in their work with ESD. The ESD expression was evident in the pedagogical principles and working methods, and the aim was that the student teachers would include similar practices in their future professions. Findings from this thesis can, hence, broaden our understanding on how teacher education programs can contribute to education *as* sustainable development.

Education *as* sustainable development is, as earlier described, related to sustainable living, where ESD is the guiding principle of the school and incorporates the school's character, community and place (Sterling, 2003, 2009; Tilbury, 1995; UNESCO, 2006). In Article II, we found that a sociocultural perspective on learning created a solid platform for the development of the social aspect of ESD. The teacher educators at NMBU aimed to treat the student teachers in accordance with values inherent in the Education Act (Ministry of Education and Research, 2016a), and to have a university culture that mirrors a sustainable school culture. A sustainable school culture is characterised by social sustainability, democracy and other founding pillars of ESD, such as appreciating the uniqueness and potential of each individual and group (Sterling, 2009). In Section 4.1.1, I described the diversity among the student teachers and the lecturers at NMBU. Findings from Article II, indicated that this diversity was appreciated and nurtured, in line with the ESD literature, where pluralism and heterogeneity are acknowledged (Wals, 2011).

Furthermore, initiatives such as the mentor arrangement discussed in Article II and the residential field course analysed in Article III were organised both to develop a safe learning environment in the teacher education program and for the student teachers to experience these arrangements' contributions in creating a positive learning environment. Schools and teachers as models for sustainability has also been emphasised in the literature (e.g. Cotton & Winter, 2010; Littledyke & Manolas, 2010), and is connected to *the realistic approach* that was introduced by Korthagen (2001) in order to bridge the gap between the theory the student teachers learn in the teacher education program and the actual practice for the teachers. The realistic approach builds on concrete experiences and the concerns and gestalts these evoke. Thus, the student teacher may by observing the teacher educators and fellow student teachers integrate or distance themselves from patterns of their behaviour, values or attitudes. Hence, through exemplary teaching and a learning environment, which strongly acknowledges social sustainability, the student teacher experiences a sustainable culture and education *as* sustainable development.

However, a problematic issue revealed in our studies concerning exemplary teaching was related to how explicit the teacher educators were with respect to the ESD realisation in the teacher education program. In both Articles II and III, we saw a pattern that some student teachers embraced the focus on ESD or an aspect of the ESD realisation (e.g. the learning environment and social sustainability), while other student teachers found it to be absent or only vaguely realised. It could, hence, seem like many of the student teachers needed more guidance and explicit teaching in order to reveal the ESD expression. An important question is, therefore, how we can make the focus on ESD accessible to *all* student teachers.

In Article II, we found that the student teachers revealing the ESD expression founded it in their own interpretation. According to our results, the justification for the deliberated choices made of the teacher educators was not always shared with the student teachers, and could be one reason for the discrepancy, because some student teachers may remain unaware if the aspect is not made explicit enough. In Article II, we therefore suggested to include more conscious metacognitive reflection related to how ESD was realised. Korthagen (2001) emphasised the importance of student teachers learning how to reflect and being stimulated to reflect, since they may 'become aware of their learning needs, to find useful experiences, and to reflect on these experiences' (p. 256). In the teacher education program under study, reflection and self-regulated learning were addressed through an emphasis on student logs. It could, however, seem like some student teachers struggled with the transferability into other teaching experiences and did not reflect on the purpose of these activities. It would therefore be beneficial to provide more opportunities for reflecting on the experiences. Reflective practice is desired in teacher education in general and particularly in ESD, since reflective teachers question their knowledge, assumptions and practices (Tal, 2010).

Another plausible explanation for student teachers not revealing the ESD expression is linked to the different understandings of ESD introduced in Chapter 2. In Chapter 3, I referred to how the Norwegian curricula may be interpreted differently based on the background of the reader, and that different readers may perceive ESD as being differently realised (Sandås & Isnes, 2015). The same is true in the teacher education program; it is reasonable to expect that the identity and the educational and cultural background of the student teachers will affect both what they learn and what they consider to be ESD in the teacher education program, because one's identity influences one's aspirations, motivation and effort in different aspects of life (Browne, 2012). It is therefore important to consider what teachers, student teachers and pupils bring to school (i.e. their positionalities) and to consider the different understandings of 'social realities' in order to create educational strategies that enhance learning (Hart, 2007). When some student teachers in our study found ESD to be poorly realised, it could have been due to ESD not being in line with their identity and beliefs about what ESD contains, and thus the ESD expression may not have been revealed. This is especially true if they have a limited understanding of ESD, for example, with a pure emphasis on the environmental dimension. Thus, it illustrates the importance of education *about* sustainable development and the complementary nature of the categories (i.e. about, for, in and as), since all of them are needed for sufficient ESD. Furthermore, it emphasises the importance of education about ESD in teacher education programs in order to facilitate an increased understanding of ESD among the student teachers.

In this study, we did not investigate the student teachers' understanding of ESD, but the analysis of the student teachers' assignments gave some indications in this regard. In a quote in Article II, the student teacher Erik articulated: 'My year in the teacher education program has taught me that ESD is much more than imparting knowledge about ecology' (Jegstad, Sinnes, & Gjøtterud, in press, p. 18). He followed up by explaining how his understanding of ESD had changed from what we identified as a fact-based to a pluralistic teaching tradition. In Section 2.2, I presented Swedish research showing that science teachers in particular tended to lean towards the fact-based teaching tradition, and held a view of science as a collection of knowledge and lectures as the method of teaching (Borg et al., 2012). This might cause student teachers from the scientific tradition to be more susceptible of basing their teaching on the same tradition. The danger of such practice might be that future teachers inhered a fact-based understanding of ESD, missing out the holistic ESD perspective that follows the pluralistic ESD tradition.

Through his assignment, Erik illustrated a well-developed understanding of ESD. However, his assignment was more specific than ordinary. If other student teachers were to build their understanding of ESD on the fact-based tradition, they would ask for more lectures on environmental problems in order to feel that ESD had been realised, instead of acknowledging capacity building and a focus on ESD competencies. In Article II, we, therefore, emphasised that student teachers in science education may need more explicit guidance to reveal the ESD expression and achieve an increased understanding of ESD. This can further be related to the importance of making the student teachers aware of their legacy and allowing them to reflect on how this legacy affect their ESD realisation, as discussed in Article III.

Founded in perspectives addressed earlier in the extended abstract (see Sections 1.2, and 3.1), I find the importance of working with student teachers' understanding of ESD to be particularly great in the Norwegian context. One reason is the emphasis of the educational system, which has been on the environmental dimension of ESD, rather than on the global development dimensions (Ministry of Education and Research, 2012). Another reason is related to how the Norwegian ESD realisation to a large extent has been entrusted the natural sciences (Andresen et al., 2015; Sinnes & Straume, 2017; Straume, 2016); this is especially problematic, knowing that the results of the curriculum analysis, reported in Section 3.1.1, showed that the Norwegian natural science curriculum mainly emphasised education *about* sustainable development. I therefore expect that the challenge of student teachers having a fact-based understanding of ESD is particularly large in the Norwegian context.

6.2.2 Education in sustainable development and the role of outdoor education in ESD

Outdoor education is an often-used additive to the ESD repertoire and contributes with education *in* sustainable development. Even though several empirical studies have been undertaken in outdoor education, they tend to focus on outcomes related to cognitive, physical, interpersonal and affective impacts rather than sustainability (Dillon, 2012; Malone, 2008; Rickinson et al., 2004). Article III contributes with an example of how ESD was realised through a residential field course in a mountain area, where the student teachers were challenged to spot subject issues in the surroundings. Findings from this article indicated that the student teachers were inspired from each other's teaching and had, or intended to use similar teaching themselves. Other research has also shown that pre-service teachers who have positive experiences in the outdoors tend to have intentions for future teaching outdoors (Blatt & Patrick, 2014; Vadala, Bixler, & James, 2007). The importance of giving student teachers experience in outdoor education is therefore emphasised (Blatt & Patrick, 2014).

Even though outdoor education has been regarded important for public environmental concern (Malone, 2008; Palmer, 1998), Sandell and Öhman (2013) warned against a linear relationship between outdoor education and behavioural change due to the possible motives of outdoor education (i.e. instrumental and intrinsic motives). Findings from Article III showed that a field course can be an aim in itself, as articulated by a student teacher pointing to the landscape giving ‘a genuine inner desire to contribute to sustainable development, both personally and in the role as a teacher’ (Jegstad, Gjøtterud, & Sinnes, 2017, p. 17). This statement indicates success of the intrinsic motive of the field course, and visualises the link between the intrinsic motive and intrinsic motivation (R. M. Ryan & Deci, 2000). The latter is important within ESD, since learners need to be motivated for ESD to be successful (Darner, 2012). However, in line with the previous discussion, there were differences with respect to whether the student teachers revealed the ESD expression.

Another aspect for nature to make substantial impact, emphasised by Tal (2012), is the pedagogy accompanying the outdoor education. I have already addressed the role of sociocultural learning theory and how it may contribute to education *as* sustainable development. In Article III, we also pointed to how the teacher education program at NMBU included active teaching approaches, such as inquiry learning and phenomenon-based teaching, in the outdoor education. These approaches are founded in experiential learning theory (Dewey, 1938), which emphasises educative experiences and reflection on these that can lead to other valuable experiences. In the next section, I will relate active teaching approaches to education *for* sustainable development.

6.2.3 Education for sustainable development and active teaching approaches

I have earlier pointed to active pedagogy and experiential learning being emphasised in ESD (Cotton & Winter, 2010). Stevenson (2007) pointed to the contradiction that schools are biased toward individualistic, lecture-styled approaches of synthetic material, whereas what is required is a focus on cooperative, real-world problem solving of current situations. Even though lectures are useful to help the learners master the content (Slavich & Zimbardo, 2012), it is not enough as mastering content is only a part of ESD. Scholars (e.g. Evans, 2015; Hopkinson & James, 2010) therefore argue that ESD requires a move away from traditional constructivist approaches, to learner-centred teaching methods that are active and participatory.

A focus on active pedagogy will, according to Evans (2015, p. 446), ‘facilitate student interpretation and construction of knowledge that leads to deeper, more engaging, enduring and readily transferable learning, compared to traditional approaches where students passively receive information’. However, Evans et al. (2017) found in their literature review that many teacher educators emphasised engaging student teachers in experiential methods, but that there was little critical reflection of the strategies and their effectiveness within ESD.

In this section, I will therefore discuss the active teaching approaches inquiry learning and phenomenon-based teaching, since findings from Article II showed that these approaches were important elements of the ESD realisation at NMBU, and contributed particularly within education *for* sustainable development.

Starting out with *inquiry learning*, findings from this thesis showed that it has the potential of realising all categories of the elliptic ESD model, and particularly within development of ESD competencies. In Article II, we found that inquiry learning facilitated problem-solving and creativity in answering the issue given, systems thinking and critical thinking in assessing the results, and collaboration and communication in working with the issues. Nugent et al. (2012) pointed to the challenge of developing and implementing inquiry learning in science education, and recommended to combine inquiry learning with outdoor education. Dillon (2012) also emphasised this combination, pointing to how inquiry learning may give opportunities for outdoor education through investigations outside. In Article III, an example of combining inquiry learning and outdoor education is provided, where the student teachers were introduced to a real-life case, mapping the nutrients in a mountain water. In addition to the ESD competencies mentioned above, the analysis revealed that NOS was introduced through the working methods. The case itself may also lead to community engagement and can be related to 'meaningful understanding of real world application of ideas', as a part of the sustainability pedagogy (Littledyke & Manolas, 2010, p. 298) emphasised in Section 2.2.2.

Phenomenon-based teaching was emphasised throughout the year, and it was especially in force at the residential field course, where the student teachers made teaching sessions based on their surroundings. In phenomenology, the focus is on perceiving and acting in relation to the world, and the learner is encouraged to reflect on his or her immediate experiences (Østergaard, Lieblein, Breland, & Francis, 2010). An argument for including phenomenon-based teaching in the teacher education program under study was to supplement and expand the constructivist approach to science education that often is found to dominate among student teachers (Gjøtterud, 2011), and thereby contribute to a pluralistic teaching tradition. Many teaching sessions at NMBU were, as described in Section 3.2, held jointly between the teacher education programs, and the student teachers in science education, consequently, experienced teaching sessions that were founded in a vocational tradition. This inspired the student teachers in science education to use concrete phenomena as starting points, rather than abstract concepts, as pointed to in Article II.

In Article III, we found that phenomenon-based teaching provided opportunities for being affected by the environment, in line with the discussion above, about intrinsic motives and intrinsic motivation. Another important contribution revealed in Article III was the experience of stepping into something unknown. Stepping into the unknown is important in ESD, since student teachers have to step into the unknown and create a new mind set when they are going to move from the fact-based to the pluralistic teaching traditions and include new types of teaching methods. Addressing sustainability issues do also in itself require stepping into the unknown, since the teacher has to explore content knowledge without fixed answers.

A contribution of phenomenon-based teaching that I did not discuss in the articles is related to the elliptic ESD model. The analysis in Table 3 in Article III, indicates that phenomenon-based teaching, in line with inquiry learning, has the potential of realising most categories of the elliptic ESD model. Phenomenon-based teaching is in itself founded in science in context and can be related to community engagement as discussed above. Furthermore, the student teachers need to be creative problem-solvers and systems thinkers in creating the teaching activities. Based on the nature of the activity, other elements of the model can also be in force, such as the focus on a safe learning environment in the activities discussed in Article III.

6.2.4 Summarising education about, for, in and as sustainable development

In this section, I have discussed empirical findings from the thesis related to the division education *about*, *for*, *in* and *as* sustainable development. The categories are broad and I have only touched upon them with foundation in the findings from this thesis. To sum up the ESD realisation at NMBU, and the roles of outdoor education, inquiry learning and phenomenon-based teaching in ESD, I have in Table 6 related the approaches to the overview of science teacher ESD in Table 1. Even though we have investigated how inquiry learning and phenomenon-based teaching contribute to ESD, a weakness of the results is that we have not gone in-depth on these teaching approaches. Thus, in order to achieve a better understanding of the approaches, a more extensive study would have been beneficial, with an in-depth study of fewer sessions, such as the study in Article III focusing on the role of outdoor education in ESD.

Table 6: A schematic overview of elements related to science teacher education for sustainable development – extending Table 1 to include findings from this thesis

		About	For		In	As
Science teacher education	**Science education**	Theoretical knowledge about sustainability issues	Attitudes, values, capacity building, critical thinking, competencies		Education in the environment	Sustainable living Democracy
		Fact-based teaching tradition	Pluralistic teaching tradition			
		ESD 1				ESD 2
		Content knowledge	Science's methodological character	ESD competencies	Science in context	Lived ESD
		A *post-positivistic* approach to science education				
	Pedagogical education	Learner centred pedagogy, multidisciplinary approaches, active learning, metacognitive reflection, real world application			Outdoor education	Education seen as a process of social change Teachers as facilitators Schools and teachers as models for sustainability
	NMBU overall	Experiential learning and active teaching approaches			Outdoor education	Sociocultural learning Exemplary teaching
	Outdoor education	Scientific knowledge about the issue under study	Experiential learning and active teaching approaches Possibilities for both instrumental and intrinsic motives		Science in context	Opportunities for intrinsic motivation and community engagement
	Inquiry learning	Scientific knowledge about the issue under study	The learners work as scientific researchers	Problem-solving, creativity, systems thinking, critical thinking, collaboration, communication	The issue under study is related to the context, with opportunities for outdoor education	Community engagement
	Phenomenon-based teaching	Scientific knowledge about the issue under study	Pluralistic teaching tradition Problem-solving, creativity, systems thinking, etc.		The issue under study is related to the context, with opportunities for outdoor education	Stepping into something unknown Opportunities for intrinsic motivation and community engagement

6.3 *Conclusions and implications*

In this thesis, I have investigated how ESD can be realised in the education of science teachers. My contribution in this respect has been with a systematic approach to ESD that goes beyond an environmental focus. Through a case study in the teacher education program at NMBU, we have investigated how ESD was realised in a science teacher education program in Norway. We have, hence, undertaken empirical research on ESD in a field where it is reported to be insufficient (i.e. teacher education), and in a context where it up to now has been completely absent (i.e. the Norwegian). In Section 4.4.3, I pointed to the reader-based generalisability of this case study, where the reader, based on rich contextualised descriptions, is invited to generalise the findings to other context. In this section, I will bring forward some of the findings and suggest some implications for both the teacher education program at NMBU and teacher education in general.

I have earlier in this thesis argued that teaching in teacher education programs needs to be close to what pupils learn in school and that one cannot say how a teacher can realise ESD without starting out with the pupils' learning in mind. This was the foundation of the development of the elliptic ESD model in Article I, where the aim was to develop a model for realising ESD, regardless of content focus.

The elliptic ESD model is, hence, a response to research question A, addressing how secondary school chemistry education can be an arena for ESD. The elliptic ESD model is also a contribution to how ESD can be realised in science teacher education, addressed in research question B, since it can guide both teachers and teacher educators in planning and analysing their teaching. The case study in Article II further responds to research question B, with a particular emphasis on outdoor education in Article III, as a response to research question C. The aim of all three research questions was to explore how teacher education programs can facilitate for their student teachers to be competent in realising ESD.

The ESD realisation in the teacher education program at NMBU was founded in existing practice and the strengths among the teacher educators, in line with a strengths approach (McKeown & Hopkins, 2002). The teacher educators also aimed at being exemplary in their work with ESD. This included an emphasis on sociocultural learning and experiential learning theories, which according to our analysis builds a thorough foundation for the realisation of ESD. The sociocultural learning theories contributes to education *as* sustainable development and the social aspect of ESD through the university culture of the teacher education institution that mirrors the school culture of a sustainable school. Furthermore, through a focus on experiential learning and teaching approaches such as outdoor education, inquiry learning and phenomenon-based teaching, enhanced emphasis is put on education *in* sustainable development, and learner participation, which in turn can lead to education *for* sustainable development.

However, findings from this study indicated that several student teachers struggled to reveal the ESD expression. I have therefore suggested that teacher educators at NMBU analyse their own teaching in an ESD perspective and integrate reflections on the ESD realisation in their teaching.

Both exemplary teaching and the strengths approach are recommended when realising ESD, and I agree with the suggestion that teachers and teacher educators aiming to realise ESD can start out by analysing the ESD initiatives of the existing teaching and curricula. This would allow the educators to change at a conservative level, which is more doable within the frames of the system. The elliptic ESD model can serve as a tool in this analysis. However, when the model is used in teacher education programs, it needs to take into consideration both the development of the student teachers and their teaching competencies as discussed in this thesis.

Findings from this research has also, in line with previous research, revealed a need to focus on an increased understanding of the ESD terminology. This could, for example, be done by allowing the student teachers to reflect on the three teaching traditions in ESD (fact-based, normative and pluralistic), and to identify which position they hold. Such a reflection would also provide an additional knowledge dimension in the teacher education program, without ESD becoming normative, and seems to be especially important in the Norwegian context.

In this study, we have not investigated the success of the ESD realisation in the teacher education program and the effect on the student teachers. In a recently published study, Andersson (2017) pointed to a lack of literature investigating how teacher education programs affect their student teachers in terms of ESD. Thus, further studies of the teacher education program may therefore include a longitudinal study, following the student teachers into their teaching profession and examining how they work with ESD in their teaching. Another suggestion is to conduct a comparative study, comparing the approaches of different teacher education institutions to the realisation of ESD. Corcoran et al. (2004) have argued that case study research on sustainability has not lived up to its potential for improving sustainability in higher education because of lack of comparative research. Thus, analyses of entire programs – or different approaches to the same teaching approach (e.g. inquiry learning), and its effect on ESD could therefore be beneficial.

I started this thesis by pointing to the complex and multifaceted challenges the world is facing, and that the educational systems are preparing young people for jobs that do not yet exist. In agreement with other scholars (e.g. Sterling, 2009; Wals, 2007), I will conclude this thesis by emphasising the open-ended nature of ESD. What appears sustainable today may turn out to be unsustainable later, and everyone is therefore a learner in ESD; this includes pupils, student teachers, teachers and teacher educators, and we have to learn together in moving towards a more sustainable world.

6.4 Epilogue

After the conduction of this study, new regulations were set in place for the Norwegian school system, and new curricula, with sustainable development being one of three prioritised topics, are currently in development. Thus, the political intention for ESD can be considered to be increased, enhancing the possibilities for realising ESD, which up to now has mostly been dependent on the teachers. There has also been a shift in the university sector in Norway, with larger emphasis on sustainability and ESD. An example from NMBU is the new learning philosophy in line with ESD principles discussed earlier (NMBU, 2017, para 1):

> Our Learning Philosophy reflects on how we want students to develop knowledge for life during their time here at NMBU: we create inclusive learning environments and a good professional home; students are active participants in the academic community; learning is a student active process that promotes reflection and independence; students take responsibility for and manage their own learning; teachers facilitate, guide and support students in their learning process; students are an important learning resource for each other and actively participate in the teaching of their peers; and teachers promote students' learning process underway through constructive feedback.

The intentions are, in other words, in place, and the challenge is now for the academics to respond to these changes.

Furthermore, teachers and teacher educators still need to be educated to realise ESD. Some relevant books have already been published in the Norwegian context (e.g. Knain & Kolstø, 2011; Sinnes, 2015). However, with foundation in the work of scholars such as Evans et al. (2016), where teacher educators and other relevant stakeholders built networks in order to share and expand on ideas for realising ESD in preservice teacher education programs, I will also recommend to establish a Norwegian teacher education network, where higher education institutions can learn from each other.

7 References

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8 Appendices

8.1 Appendix 1: List of sessions analysed in Article II

Module[20]	Name of session	About the session
$M1_{SE}$	Reasonable use of energy demands knowledge	With a foundation in research, topics like peak-oil, phosphorous deficiency, land protection, fuel sources and renewable energy sources were covered in a lecture.
	Education for sustainable development	A lecture covered topics on how education can promote sustainable development, and how the development of the society during the last decades has created new demands for teaching, both related to ecological and social sustainability.
	Teaching for the future	In a future workshop, the student teachers worked in groups and discussed how they wanted the world to look like in twenty years. They also discussed how science education can support such a development.
	The first teaching exercise	The student teachers prepared their own five-minutes teaching sequence, which they conducted in small groups (consisting of 4-5 student teachers). The teaching sequences were thereafter analysed with foundation in a model for planning teaching.
	Shrimp party	A shrimp party was held in the afternoon of day two. In addition to eating scrimps, some teacher educators entertained with music and stories.
$M2_{P}$	Five-days module in pedagogy with class management as the main topic	Through this module, the aim was to increase the student teachers' awareness and theoretical and practical knowledge about communication (including relations, emotions and ethical awareness), group processes, conflict management and guidance. A variety of working methods were applied.

[20] Each module is presented with a number and a subscript. The subscript illustrates whether the module was in science education (SE) or pedagogy (P)

M3SE	Safety course	All Norwegian science teachers have to attend a mandatory course in laboratory safety. In addition to covering topics directly relevant to safety, the course also covered topics related to how to work sustainably in biology (e.g. measures taken during and after experiments with animals, plants and microorganisms, and physiological experiments).
	Teaching preparation	The student teachers were introduced to different educational planning tools (e.g. 'the reverse curriculum approach', 'big ideas') and there was also emphasis on class management.
	Finse as an arena for teaching and learning	This was the first session at Finse, and a retired biology teacher who has brought pupils to Finse for several years held a lecture about Finse as an arena for learning science. The lecture covered topics on geology, plants' and animals' adaptations to the mountain climate, and issues related to biodiversity in the mountain areas.
	Teaching stations founded in Finse	In this session, the student teachers could choose between three of the following five teaching stations: aesthetics at Finse, outdoor chemistry, the mathematics and physics in the Railway Navvy Museum, botanical fieldwork and biology at Finse.
	Educational planning in groups	The student teachers prepared and performed a short teaching session. They worked in groups and chose what topic they wanted to teach. The surroundings was supposed to be used as foundation for their teaching.
	Teaching in groups	In addition to planning and performing their own teaching session, the student teachers gave feedback and guided other groups in their teaching.
	About outdoor education	A lecture was held with some group work included. The topics in focus were why we should bring pupils outdoors; different types of outdoor education; laws and regulations for outdoor education; the challenges of bringing pupils outdoors; important elements in good outdoor education; important factors for the outcomes of outdoor education; and suggestions for useful webpages within outdoor education.
M4P	Five-days module in pedagogy with 'adapted education' as the main topic	The student teachers worked with how they could concretise adapted education both in their own teaching and in the school as an entity. Light was also shed on adolescence and how the student teachers could, together with their colleagues, facilitate for a good learning environment. Some time was also allocated to the starting phase of the development projects.
M5P	Five-days module in pedagogy with 'learning theories' as the main topic	In this module, different learning theories were presented. The student teachers worked particularly with experiential learning and sociocultural learning theories. Other topics covered were: learning strategies, learning styles, action learning, action research and pedagogical analysis as a strategy to develop a good learning environment.

M6SE	Using the Norwegian Core curriculum	In a lecture about the Norwegian curricula, given by a representative from the Norwegian Centre for Science Education, the core curriculum was related to the subject curricula and ESD. The importance of outdoor education in ESD was particularly emphasised. There were also given examples of how resources from the Norwegian Centre for Science Education can support teachers in realising ESD.
	Reflection on practical training	The student teachers worked in groups, presenting and discussing cases from their practical training. These experiences were further used to discuss a model planning teaching, and related to ESD competencies.
	Introduction to learning science	A lecture covered topics on scientific literacy, NOS, the role of concepts in science, and different forms of practical work. The lecture was followed up in subject-specific groups.
	'Taste of practical training'	A long table was set and all student teachers and teacher educators ate lunch together. The student teachers provided food that was connected either to their home town or to their practical training. Both student teachers and teacher educators contributed with entertainment.
	Collaborative learning	The student teachers were introduced to different forms of collaborative learning through a lecture and exercises.
	'The teacher's double role'	The session focused on the importance of seeing and hearing each individual pupil. Other topics emphasised were how to approach the unexpected from the pupils and how to deal with the pupils' scientific preconceptions in a sensitive way.
M7SE	Using roleplay to teach complex issues	The session included a lecture addressing theory and examples of role play as teaching method. The student teachers also participated in a role play about gene testing.
	Introduction to activity-based teaching	The student teachers got an introduction to how teaching modules could be created from an activity, using the reverse curriculum approach.
	Introduction to phenomenon-based teaching	The student teachers were introduced to phenomenon-based teaching and the aim of the session was to give the student teachers a practical method to apply in their educational planning.
	Inquiry learning	Through lectures and group work, two days were allocated to work with inquiry learning. The topics covered were the characteristics of inquiry learning, the role of the teacher in inquiry learning, assessment in inquiry learning and examples from different projects. The students were also allowed to work with their own subjects to create their own examples.
M8P	Five-days module in pedagogy with the topic 'the school as an organisation'	In this module, the student teachers worked with colleague guidance and school development. The student teachers were also allowed to practice colleague guidance, when supervising each other on the pedagogical development projects.

M9SE	'A nation of dinks'	A lecture about farmers, the Norwegian agricultural policy and sustainable development. The lecture was founded in the Norwegian book 'En nasjon av kjøtthuer' ('A nation of dinks').
	Teaching modules	School garden: The student teachers were presented with possibilities and challenges of using school garden as an arena for teaching and learning.
		The photosynthesis and combustion: In a session founded in phenomenon-based teaching, the student teachers were allowed to investigate the phenomena related to these topics.
		History of science in physics teaching and learning: The aim of this session was that the student teachers should achieve insight in possibilities and challenges in using history of science in teaching and learning the distinctiveness of science. Much emphasis was laid on NOS and the role of the scientist in developing theories.
	SSI and use of media in teaching and learning	In this session, the use of media in teaching and learning science was addressed. The session also included discussion of the challenges in determining 'the truth', and the importance of viewing science as both a process and a product.
	The distinctiveness of science	This particular session was centred on scientific working methods. The emphasis was put on what the pupils should know about scientific working methods and how teachers' views on NOS affect their teaching.
M10P	Five-days module in pedagogy with 'ethics' as the main topic	The aim of this module was to make the student teachers aware of their ethical responsibilities as teachers. The student teachers worked with the professional code of ethics and identified ethical dilemmas in teaching situations. Pupils' rights, bullying, and children and youth in crisis were other topics covered.
M11P	Five-days module in pedagogy summarising the academic year	In this module, the topics from the pedagogical modules were summarised, with an emphasis put on learning theories. The student teachers also presented their pedagogical development projects and provided feedback to each other as 'critical friends'.
M12SE	Examples of ESD from secondary schools	Two examples of ESD projects in schools were presented. The first presentation was about a specific energy- and environmental study program at an upper-secondary school. The second presentation was from the Windmill project presented in Chapter 4.
	Competencies for ESD in the teacher education program	The student teachers were divided into groups and discussed different ESD competencies and how these had been addressed throughout the teacher education program.
	A curriculum in the light of ESD	The student teachers discussed how ESD can be realised within the current curricula.
	Theoretical perspectives on ESD competencies	Different theoretical perspectives from the teacher education program were summarised (e.g. inquiry learning, phenomenon-based teaching and activity-based teaching) and related to ESD.

General perspectives of the teacher education program	Log	Log is widely used in the teacher education program to increase the ability of the student teachers to reflect. Time was allocated most days to reflect on given perspectives related to their role as teachers.
	Student democracy	Class representatives are elected each year to be spokespersons for the student teachers. There are also student representatives in all boards at the university.
		Each module has a designated session where the class representatives bring forward topics they want to discuss. There are also written evaluation after each module. The responses are summarised and discussed in meetings.
		The student teachers have several informal ways to give feedback to the teacher educators. These include plenary sessions related to the log sessions and conversations with supervisors. All student teachers who express dissatisfaction are invited to a meeting with the leader of the teacher education institution and other staffs related to the issues.
	Practical training	The student teachers have twelve weeks of practical training, where a particular emphasis is put on the societal relevance of their teaching.

8.2 Appendix 2: Interview guide 1 (with Astrid, Solveig and Hans Erik about ESD in the teacher education program)

1. What is your role in the teacher education program? (Hva er din rolle i lærerutdanningen?)
2. Can you tell me about SLL in a historical perspective? (Kan du fortelle meg litt om SLL i et historisk perspektiv?)
3. What is your understanding of ESD? (Hva legger du i UBU?)
4. What is your background within ESD? (Hvilken bakgrunn har du med UBU fra tidligere?)
5. Can you tell me about the process in which ESD became an overall aim of the teacher education program? (Kan du fortelle meg litt om prosessen som foregikk i forbindelse med at UBU ble gjort som et overordnet mål for seksjonen?)
6. What was your role in this process? (Hvilken rolle hadde du i denne prosessen?)
7. What did you find important in this process? (Hva vil du trekke frem som viktig i denne prosessen?)
8. To what extent is ESD realised in the teacher education institution? (I hvilken grad føler du at UBU er et fokus per i dag (i forskning, undervisning, ellers)?
9. How do you realise ESD in your own teaching? (Hvordan inkluderer du UBU i undervisningen?)
10. Do you have any plans for future ESD? (Har du noen forslag til hva du kunne gjort innen UBU utover det du gjør i dag?
11. What are your visions/dreams with respect to the realisation of ESD at SLL? (Hva er dine visjoner/drømmer i fht UBU på LUR/PPU/seksjonen?)

8.3 *Appendix 3: Interview guide 2 (with Edvin about phenomenon-based teaching)*

1. How is phenomenon-based teaching introduced to the student teachers? (Kan du fortelle meg litt om hvordan fenomenbasert undervisning introduseres til studentene?)
2. What is your perspective on how phenomenon-based teaching contributes within ESD? (Hvordan mener du at fenomenbasert undervisning bidrar til UBU?)
3. Several student teachers write about either inquiry learning or phenomenon-based teaching in their assignments. Do you see any synergetic effects with respect to ESD that could have been achieved by merging the two approaches? (Mange studenter skriver om utforskende arbeidsmåter eller fenomenologi i sine oppgaver. Ser du noen sammenheng eller synergi mellom de to tilnærmingene og muligheter for å oppnå en større helhet dersom man slo disse to tilnærmingene sammen?)

8.4 Appendix 4: Interview guide 3 (about ESD in the pedagogy modules)

1. How do you work with ESD in the modules in pedagogy? (Hvordan jobber dere med UBU i pedagogikkmodulene?)
2. Follow-up questions:
    a. How do you work with critical thinking in the modules in pedagogy? (Hvordan jobber dere med kritisk tenkning i pedagogikkmodulene?)
    b. What about the link to the local environment? (Hva med linken til lokalmiljøet?)

PART II:

THE ARTICLES

Chemistry Teaching for the Future: A model for secondary chemistry education for sustainable development

Kirsti Marie Jegstad and Astrid Tonette Sinnes (2015)

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Abstract

For more than 40 years, the international community has acknowledged the role education might play in environmental awareness and conservation. The last major initiative came when the United Nations General Assembly proclaimed a Decade of Education for Sustainable Development (2005–2014). In the final year of the decade, teachers still struggle to realise education for sustainable development (ESD). One of the challenges teachers face with respect to ESD is the inclusion of even more content into an already overloaded curriculum. In response, it has been suggested that ESD should be introduced as an integrated perspective across the content of all existing subjects. This paper offers a model for how ESD can be realised in chemistry education. The model has been developed to support chemistry teachers in their educational planning and consists of 5 categories: chemical content knowledge, chemistry in context, the distinctiveness and methodological character of chemistry, ESD competences and lived ESD. The ESD model is illustrated through 5 ellipses, visualising the hierarchy of the categories, as they exist in different levels. All 5 ESD categories need to be considered in a holistic ESD approach.

Introduction

Mass media is a daily reminder of the challenges the world faces, especially in terms of the currently accelerating ecological crisis. From a global perspective, climate change, poverty, pandemics and the lack of pure water and phosphorous are only some of the problems threatening the sustainability of our planet. These problems are expected to accelerate as human pressure on the earth system continues to increase (United Nations Environment Programme, 2012). Working toward a development 'that meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commision on Environment and Development, 1987, p. 8) is even more urgent today than when the Brundtland commission presented this definition of sustainable development in 1987.

Education has been recognised as 'indispensable' for achieving sustainable development (United Nations, 2002). Hence, the United Nations proclaimed the decade from 2005 to 2014 to be the international Decade of Education for Sustainable Development. The idea was that governments of all UN member countries commit themselves to focusing on how education could contribute to sustainable development (UNESCO, 2005b).

Chemistry education is considered to have a central role in education for sustainable development (ESD) (Bradley, 2005; Burmeister & Eilks, 2012). This is based on the core roles that chemistry and the chemical industry might play in sustainable development. Because many products in our daily lives are based on chemistry, the chemical industry has a major potential for focusing on the environment in terms of both the production process and the end product. Hence, it has been claimed that chemistry education should emphasise learners' understanding of the role of chemistry in society and increase their ability to evaluate chemistry-related businesses and products, such as how chemistry can affect the future, contribute to sustainable communities and aid in the proper stewardship of natural resources (Burmeister & Eilks, 2012; Wheeler, 2000).

Chemistry is also important in sustainability issues outside the professional world. Chemical knowledge is necessary for lay people to understand many issues that threaten the sustainability of our planet, such as the mechanisms behind climate change and the potential side effects on our personal lives caused by the production of goods, alternative energy production, etc. (Burmeister, Rauch, & Eilks, 2012; Schmidt & Wolfe, 2009). The pupils of today will become voting citizens who make decisions that involve applications of chemistry.

Thus, understanding chemistry concepts will provide informed support for making such decisions (De Vos, Bulte, & Pilot, 2002; Kolstø, 2001; Ware, 2001).

Despite the importance of chemistry in ESD, studies in Germany have revealed that both experienced teachers (Burmeister, Schmidt-Jacob, & Eilks, 2013) and student teachers (Burmeister & Eilks, 2013a) struggled to apply the ideas of ESD and green chemistry in their teaching. These findings concur with a Norwegian study (Sinnes & Jegstad, 2011) that found that science teachers educated for ESD and with an outspoken desire to include ESD in their teaching were not able to do so after their graduation because of the lack of facilitation in the schools. Formal secondary education in Norway has been accused of not prioritising ESD (Brænden, 2008; Koller, 2009; Laumann, 2007; Raabs, 2010; Schreiner, 2006). This phenomenon has been recognised in other countries as well (Palmer, 1998). Other challenges frequently cited as problematic within ESD include time constraints caused by overloaded subjects, lack of teaching resources and issues associated with the subject discipline (Barrett, 2007; Palmer, 1998; Sandell, Öhman, & Östman, 2003).

To overcome these challenges, we present a model for applying ESD from an integrated perspective derived from the already existing subject of chemistry. Thus, we visualise how ESD can be realised in the teaching of chemistry regardless of the focus and subject workload of existing curricula. The model for planning teaching and learning in chemistry presented here attempts to bridge the gap between the school and 'an ideal and sustainable world'. The model is outlined through a theoretical discussion of how aspects of ESD can be integrated into chemistry education and the following research question is posed: How can secondary school chemistry education be an arena for ESD?

Although this paper provides a within-discipline approach to ESD (Stables & Scott, 2002), the interdisciplinarity that is emphasised in much of the ESD literature (cf. Wals & Jickling, 2002) is also addressed. A key element in ESD is the importance of acknowledging the interrelatedness between the ecological, social and economic dimensions of any issue. While we concede that it is not necessary for one teacher to consider all perspectives of ESD and that collaboration among teachers of different subjects may be beneficial (Borg, Gericke, Höglund, & Bergman, 2012), we still insist that all chemistry teachers should be able to include the ecological, economic and social perspectives of the chemical topics they teach. Thus, we stress that the ability to assess how chemistry affects and is affected by other disciplines is a part of the general education of the chemistry teacher and therefore an integrated element in the model.

Before introducing our model of ESD in chemistry, we will present the perspectives of ESD on which the paper is built. We will also discuss scientific literacy and its relevance to ESD.

Background

Since its introduction, the concept of sustainability has taken on many different meanings and remains highly contested. A study by Dobson (1996) revealed more than 300 different meanings of the terms 'sustainable development' and 'sustainability'. A common division is between those who prioritise 'sustainable economic growth' and those who prioritise 'sustainable human development'. The first group adheres to the current social and economic system and emphasises 'the role of technological and economical tools in shifting individual, group and industry activities toward a more sustainable path of economic development' (Fien & Tilbury, 2002, p. 3), whereas the second group focuses on social equity and ecological limits. The latter calls for radical changes in the social and economic system, questioning the present worldview of unlimited economic growth (Fien & Tilbury, 2002; Orr, 1992). There are, however, several nuances to this picture. Due to different understandings about the concept of sustainable development, a myriad of understandings of what ESD is and could be also exists in the ESD literature (de Haan, 2010; Fien & Tilbury, 2002; Gough & Scott, 2006; Huckle, 1996; Orr, 1992).

Combes (2009) claimed that ESD is 'a learning process and an approach to teaching based on the ideals and principles that underlie sustainability' (Combes, 2009, p. 6). Due to the various understandings of sustainability, ESD is, however, not an agreed-upon set of ideas that educators can simply apply to their teaching. Teaching approaches and topics differ according to local contexts and priorities (UNESCO, 2005b, 2012). Sterling (2010) warns against a consensus within the concept of ESD, since a too narrow definition of ESD could cause policies, theories and practices outside the stated boundaries to assume that ESD is not their concern. In addition, it is important to remember what Wals (2011, p. 179) reminded us: 'what may appear to be sustainable behaviour today may turn out to be unsustainable later in time'. He emphasised the importance of avoiding indoctrination into a set idea of what sustainable development means and rather 'focus on the kind of capacity building and critical thinking that will allow citizens to understand what is going on in society, to ask critical questions and to determine for themselves what needs to be done' (Wals, 2011, p. 179).

Summers, Childs and Corney (2005) referred to a definition of ESD from the British government's Sustainable Development Education Panel when they stated:

> [e]ducation for sustainable development enables people to develop the knowledge, values and skills to participate in decisions about the way we do things individually and collectively, both globally and locally, that will improve the quality of life now and without damaging the planet for the future. (p. 629)

An important aspect of this interpretation is that ESD does not necessarily concern a specific sustainability issue. By all means, ESD may very well deal with a sustainability issue, but the main emphasis is promoting skilled participation in future decisions both locally and globally in a manner that does not negatively affect future generations. A key concept in this respect is the precautionary principle, which emphasises taking action to protect human health and the environment against possible future damage (UNESCO, 2005a).

Burmeister et al. (2012, p. 59) are of similar thinking, emphasising: '[t]he central focus of ESD is to prepare the younger generation to become responsible citizens in the future'. The definition of ESD from Summers et al. (2005) and the broad notion of becoming *responsible citizens* provide an important foundation for this paper. The notion of responsible citizens points to respect for other human beings (both present and future generations) and for the planet and what it provides (e.g. resources, flora and fauna), which is a founding value of ESD (UNESCO, 2006). Moreover, the notion of becoming responsible citizens points to Klafki's (2000) three dimensions of pupils' capacities: self-determination, participation and expressing solidarity with others. Various levels and dimensions of education must be taken into consideration when educating for sustainable development. There is a need for both taking up socially relevant issues and a general education for societal participation (Burmeister & Eilks, 2013a).

Societal changes continuously increase the demands on and challenges for schools (Kind, 2003). The aims and content of science education are therefore the subjects of a long-debated issue that concerns the relevance of science education (Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). An important question is whether the way science is taught in schools provides learners with the knowledge and skills necessary to take part in—and secure—sustainable development. In other words, does science education prepare pupils to make informed decisions in authentic contexts? In their report 'Science Education in Europe: Critical Reflections', Osborne and Dillon (2008) pointed to the problem that European science curricula seemed to prepare learners for a science degree instead of meeting the necessities of the majority of pupils who need a broader overview of science. Most pupils need a general science education that prepares them for a critical informed participation in society. Roberts (2011) pointed to the same discrepancy in his distinction between Vision I and Vision II of scientific literacy. Vision I aims to develop ‘a potential pool of scientists’, focusing on the products, processes and the characteristics of science. Vision II focuses on the relevance of science to ‘a variety of science-related situations that confront adults as parents and citizens’ (Roberts, 2011, p. 14). In a knowledge society, there is a need to shift from the scientific literacy of Vision I towards Vision II, which would result in an intermediary position in which both Vision I and Vision II are present (Aikenhead, Orpwood, & Fensham, 2011). The challenge is to develop a science education that prepares pupils for life in a global knowledge society and at the same time provides them with the capability and induce the desire needed to promote sustainable development.

ESD scholars are acknowledged as some of the best known ‘advocates’ of Vision II of scientific literacy (Roberts, 2011), together with scholars from the science–technology–society movement and the field of socio-scientific issues (Pedersen & Sadler, 2012). Scientific literacy is considered important in order to enable pupils to adapt to the challenges of a rapidly changing world; it is also considered crucial in solving many sustainability issues as a ‘means of enhancing democracy and responsible citizenship, and resisting the consumer juggernaut’ (Hodson, 2008, p. 14). The ability to deal with socio-scientific issues is an integrated component of scientific literacy (Colucci-Gray, Camino, Barbiero, & Gray, 2006). When citizens are able to evaluate and make informed decisions about scientific and socio-scientific matters of personal and public concern, democracy, which is an important element in ESD (Sandell et al., 2003), is strengthened (Hodson, 2008).

In order to make real-life personal decisions and to participate in discussions of scientific issues that affect society, pupils not only need knowledge of scientific content, but also an understanding of how reliable and valid data are collected and interpreted. They need to recognise the tentative character of scientific knowledge and to understand how human interests may shape the process and products of science (Gräber, 2000; Hodson, 2008; Kolstø, 2000). We will therefore build on the literature on both scientific literacy and ESD in our presentation of the ESD in chemistry model. Because sustainable development in itself can be considered a socio-scientific issue (Simonneaux & Simonneaux, 2012), we will also build on the literature from the field of socio-scientific issues.

According to Bybee (1997), the ultimate aim of scientific literacy is *multidimensional scientific literacy*, where students 'begin to make connections within scientific disciplines, and between science, technology, and the larger issues challenging society' (Shwartz, Ben-Zvi, & Hofstein, 2006, p. 205). This kind of scientific literacy demands

> developing social values such that a person can act in a responsible manner, . . . being able to function within the world of work at whatever the skill or responsibility level and possessing the conceptual background or skills of learning to cope with a need-to-have, relevant public understanding of science and technology in a changing society. (Holbrook & Rannikmae, 2007, p. 1353)

These aspects are much in line with the aims of ESD as expressed earlier. We will in particular lean towards the definition of chemical literacy given by Shwartz et al. (2006) that includes four domains they consider necessary to be a chemically literate person (i.e. a graduate of secondary school): general scientific ideas and characteristics of chemistry, chemistry in context, higher order learning skills and affective aspects. These domains will be explained more in depth throughout the paper.

A Chemistry ESD Model

From a broad educational perspective, the chemistry classroom can be an arena for the development of general skills in addition to chemistry-specific skills and knowledge. This is in line with the notion of 'education through chemistry' (Holbrook & Rannikmae, 2007), which includes a shift 'from learning chemistry as a body of knowledge to promoting the educational skills to be acquired through the subject of chemistry' (Holbrook, 2005, p. 4). Thus, the realisation of ESD in the chemistry classroom may not necessarily involve a specific chemical sustainability issue. The teacher may instead, regardless of the chemistry topic being taught, emphasise teaching and learning approaches that promote the development of respect and responsibility among pupils and facilitate the development of the competences pupils need in their daily lives and as adult citizens in a sustainable world.

Burmeister et al. (2012) have presented four strategies for implementing issues of sustainable development in formal chemistry education. They suggest that the following strategies should be implemented in combination for the best possible inclusion of ESD in chemistry education: 1) the adoption of green chemistry principles in *the lab work*, 2) the addition of sustainability strategies as *content* in the chemistry education, 3) the inclusion of *socio-scientific issues* and *controversies* in the teaching and 4) the use of chemistry education as a part of ESD-driven *school development*.

Although Burmeister et al.'s (2012) approach inspired our work, we modified and expanded the strategy, as illustrated in Figure 1. Through this figure consisting of five ellipses, we visualise a model for planning chemistry ESD. The five ellipses represent five different ESD categories, which are chemical content knowledge, chemistry in context, chemistry's distinctiveness and methodological character, ESD competences and lived ESD. The ESD categories represent different aspects of a complex whole and do partly overlap. All of them must be considered in order to achieve a holistic perspective of ESD.

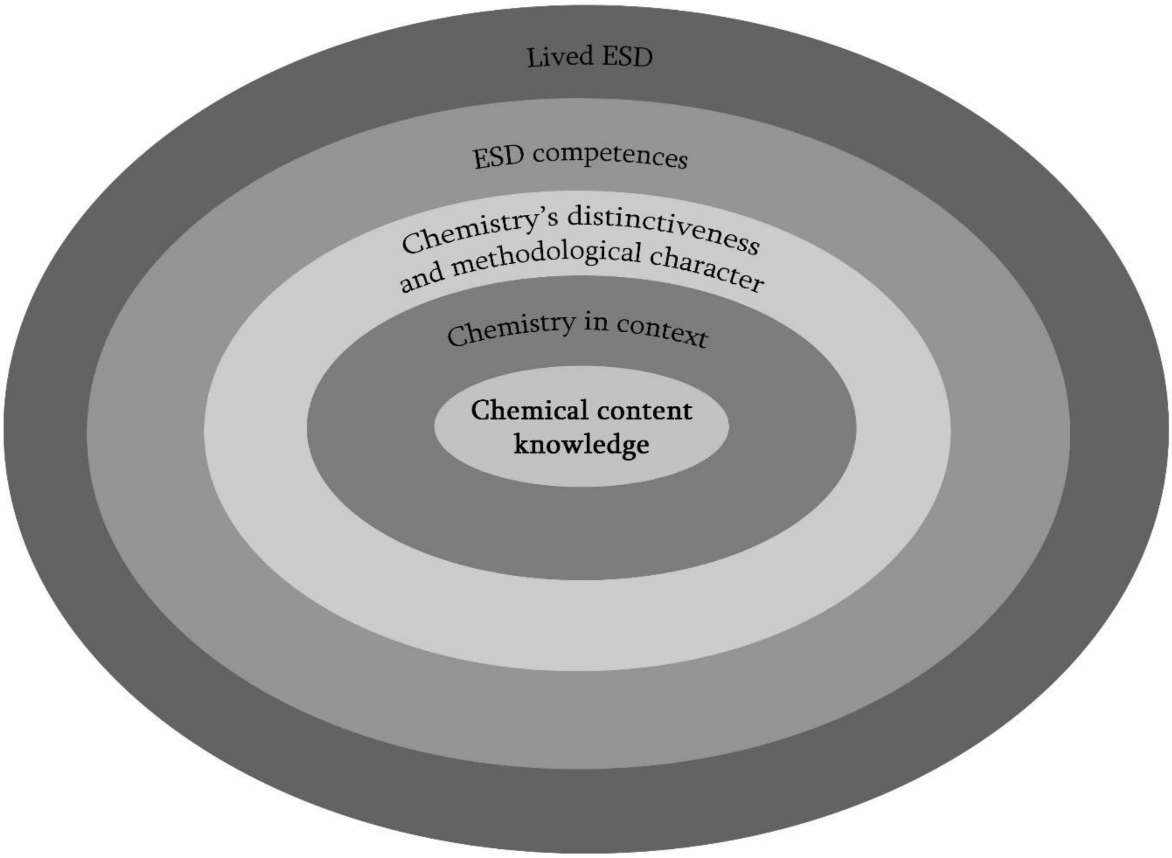

Figure 1. The elliptic model for ESD in chemistry education

The following sections explain the ESD categories and their derivation. We will explain the categories from the centre of the model outward, and therefore start with chemical content knowledge.

Chemical Content Knowledge

The central ellipsis in our model is chemical content knowledge, which is important for understanding and assessing sustainability issues. Content knowledge is important from a curricular argument, since this model is derived from the already existing subject of chemistry. However, content knowledge is also important for pupils to come to grips with socio-scientific issues (Hodson, 2013).

The chemical content knowledge category mainly concerns education *about* sustainable development and emphasises chemistry issues that are relevant for sustainable development. Such issues could be connected to water resources, the effects of acid rain, the ozone layer, oil recovery and searching for renewable sources of energy and raw materials (Burmeister et al., 2012).

A specific example of an issue that is relevant for sustainable development is the life cycle analysis of different products (Juntunen & Aksela, 2013). A life cycle analysis includes analysing the sustainability of the raw materials used in the synthetic strategy, energy use and different types of pollution created by the production process; dangerous compounds in the synthesis process or in the product itself and issues around waste and waste treatment (Böschen, Lenoir, & Scheringer, 2003). Thus, life cycle analysis is a socio-scientific teaching approach that combines green chemistry, sustainable chemistry and engineering in order to evaluate the environmental burden of a product, process or activity (Juntunen & Aksela, 2013). Topics that can be discussed are among other topics such as water footprint, resource scarcity and the use of different types of materials.

An important aspect of the chemical content knowledge category is the great responsibility given to the teacher with respect to selecting examples and context. Via relevant examples, the pupils will get insight into and knowledge about different sustainability issues. Furthermore, content knowledge in chemistry concerns more than just the issues that are *directly* relevant for sustainable development: background knowledge is also important for understanding the chemistry behind sustainability issues. For example, an understanding of solubility, equilibrium and electrochemical series may be necessary to understand how different substances affect nature.

However, in an ESD-oriented classroom, a sole emphasis on content knowledge is not enough. For example, dealing with the controversial topic of biofuels, where chemical content knowledge is clearly important, the topic should also be considered within a relevant context and with emphasis on specific competences (e.g. systems thinking and normative competence). We will return to the explanation of ESD competences later in this paper, while in the next section, we will proceed with the importance of connecting the content to a relevant context.

Chemistry in Context

Understanding the relations and interdependence of nature, society and the economy is considered crucial to achieving sustainability. Thus, the subject of chemistry must be taught in a relevant context in order to promote full understanding of current sustainability issues. School science engages pupils the most when pupils consider it relevant to their lives and interests (Osborne & Collins, 2001). However, Osborne and Collins (2001) found that physics and chemistry education are less connected to pupils' experiences than are certain topics in biology, such as human biology. Other researchers have also accused chemistry teaching of being irrelevant to pupils' daily lives and have criticised the chemistry curricula for placing the subject first and making its application a poor second (Gilbert, 2006; Holbrook, 2005). This critique has shown that there is significant room for improvement when it comes to making chemistry education context-oriented and relevant for pupils' personal lives.

Stuckey et al. (2013) discussed relevance in science education and defined relevant science education as education that has positive consequences for the pupil–either by fulfilling actual present needs or by fulfilling anticipated future needs. They differentiated between three levels of relevance (individual, societal and vocational) and covered both intrinsic and extrinsic dimensions (Stuckey et al., 2013). From an ESD perspective, the individual dimensions can be exemplified through 'skills for coping with personal life in [the] future' and 'acting responsibly and solidaric in [the] future' (Stuckey et al., 2013, p. 19). The societal dimension is similarly connected to ESD through examples at an extrinsic level: 'learning how to behave in society' and 'behaving as responsible citizens' (Stuckey et al., 2013, p. 19).

Dillon (2012) pointed to the mutual benefits of realising sustainability issues in both teaching and learning. Pupils become more interested in learning science and they will learn about specific sustainability issues, which in time may contribute to a sustainable future. Thus, the use of specific sustainability issues as a point of departure is a good way to increase the relevance of the subject *and* shed light on a sustainability issue; this can be done on a local level by focusing on sustainability issues in local society. On a global level, the frame of reference could be a specific issue of global sustainability, such as increasing temperatures. Although rising temperatures is a global issue, the consequences vary according to geographical location. As in most global sustainability issues, we do not necessarily experience the consequences, but we are important contributors to their occurrence. This holistic perspective fosters systems thinking as thoughts and beliefs about the future. It also points to a need to care about how we affect other people. Empathy is crucial in order to show respect for both other human beings and the planet; therefore, it is also important for fostering responsible citizens.

Another aspect of the ESD category is connected to the actual teaching of chemistry in other contexts. Experiences in the natural world have an important influence on people's thinking in relation to the environment (Malone, 2008; Palmer, 1998), but the positive experiences need to occur over long periods of time (Hungerford & Volk, 1990). Consequently, including outdoor education in chemistry may have the positive effect of engaging the pupils in sustainability issues and caring for nature (Sandell & Öhman, 2010).

Fieldwork is common in science education, but mostly in biology and geology, where field trips are considered to be an essential part of the subject (Borrows, 2004). Because outdoor education is an important element in ESD (Sandell & Öhman, 2010), it should be integrated in all subjects, including chemistry education. Education in natural environments has rarely been included in the subject of chemistry, and little literature in this field is available. However, some research has focused on linking industries and schools (Coll, Gilbert, Pilot, & Streller, 2013; Hofstein & Kesner, 2006). Using an industry as a site for outdoor education could be beneficial, because learning is made more authentic due to more practical and realistic learning areas (Coll et al., 2013). Thus, scientific questions from everyday life can be discussed, and pupils get experience in objectively evaluating information and get a balanced view of industrial processes (Hofstein & Kesner, 2006). Industrial contexts that include issues related to health and environmental products the pupils use in their daily lives could be beneficial both from a sustainability perspective and when it comes to enhancing pupils' interest and motivation to study chemistry.

Chemistry's Distinctiveness and Methodological Character

The third ellipsis in the model concerns two aspects: applying sustainable practices in chemistry and addressing the nature of chemistry. Central to chemistry education is the significance of three different levels (Johnstone, 1991). The *macro level* requires describing chemicals and conducting experiments in the laboratory. The chemical reactions at this level can be explained through the different particles and their organisation at the *sub-micro level.* At the *symbolic level*, findings and considerations are reported through formulas, chemical equations and calculations (Herron, 2005; Johnstone, 1991). To understand chemistry, pupils must move across these levels (Ware, 2001). Hence, in chemistry education, practical laboratory work, which is considered essential in developing student knowledge in science (Miller, 2004), is particularly important.

Issues related to sustainable chemistry are often connected to synthesis design and how chemistry and chemicals affect the environment (Böschen et al., 2003). The first aspect of this ellipsis is therefore linked to how to work sustainability into chemistry. Pupils may learn about sustainable industries and *green chemistry* in the laboratory. Green chemistry principles mean working on a small scale to reduce the production of waste, use environmentally friendly chemicals, conserve materials and energy, etc. (Karpudewan, Hj Ismail, & Mohamed, 2011; Ware, 2001). This might be more applicable in tertiary education than in secondary education because tertiary education features greater and more diverse laboratory work. However, awareness can and should be created as early as in secondary school. An early introduction to green chemistry could create different mindsets among pupils, where they consider the environmental effects and are not solely concerned with maximising the experimental yield of the chemical reaction (Ware, 2001). Hence, emphasising green chemistry could contribute to not only an understanding of scientific knowledge and the development of that particular knowledge, but also attitudes and values that are important when realising ESD. In this respect, chemistry education should also centre on philosophical and ethical questions related to the production of chemical knowledge and its applications (Colucci-Gray et al., 2006).

The second aspect of this ellipsis is the nature of chemistry. The nature of chemistry largely includes the nature of science and is therefore connected to the following characteristics of scientific knowledge: it is tentative and never absolute or certain; it is empirically based; it is subjective and therefore influenced by the scientists' beliefs, previous knowledge and experiences; it involves human inference, imagination and creativity and it is socially and culturally embedded (Lederman & Lederman, 2012). According to Kolstø (2000, p. 647), 'the human and social aspects of the product of scientific knowledge have been underemphasized in science teaching'. A chemically literate person understands that chemistry is an experimental subject, whereas chemists make generalisations and suggest theories to explain the world based on scientific inquiry (Shwartz et al., 2006). Learning about scientific research methods is therefore considered an important part of understanding the nature of science (Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). This is especially valid for the nature of chemistry due to the importance of laboratory work and the significance of the three different levels that are distinctive to chemistry (Johnstone, 1991, 2000).

Chemistry can, due to the long-time existence of the chemical industry, be considered both a technology and a science (Sjöström, 2007). Hofstein and Kesner (2006, p. 1018) claim that 'teaching chemistry without incorporating aspects of the chemical industry ignores one of the most important features of modern life and its technological achievements'. They further contend:

> We live in an era in which chemistry should be presented to the student not only as a body of knowledge, but also as a vehicle for presenting the technological manifestations of chemistry and its influence on the students' personal life and the society in which he/she lives. (p. 1037)

The nature of chemistry therefore also includes the role of technology in society.

ESD Competences

The next ellipsis is ESD competences. An important outcome of ESD is developing competences that are considered relevant to contribute to a sustainable future. A competence-based approach to scientific literacy that emphasises ethical competence, communicative competence and other competences encompassing socio-scientific decision making skills has been highlighted by scholars in the fields of scientific literacy (Gräber, 2000; Holbrook & Rannikmae, 2009) and ESD (de Haan, 2010; OECD, 2005; Salganik, Rychen, Moser, & Konstant, 1999; UNECE, 2011; Wiek, Withycombe, & Redman, 2011). Competences are seen as crucial 'to tackle the current problems of humankind and the earth' (Rauch & Steiner, 2013, p. 11), but also to live a life in the knowledge society–where the educational systems have to prepare young people for jobs that do not yet exist (Voogt & Roblin, 2012).

The term *competence* has been interpreted and defined in many ways (Sleurs, 2008; UNECE, 2011; Weinert, 2001). It can be investigated from many perspectives and is therefore considered difficult to define (Kauertz, Neumann, & Haertig, 2012). One definition is 'the ability to meet demands of [a] high degree of complexity' (Rychen & Salganik, 2000, p. 67). As a part of the OECD's project, Definition and Selection of Competences (DeSeCo), Weinert (2001) presented a list of ways in which the term has been defined, described and interpreted theoretically. Despite a thorough analysis, he provided no unified definition of the term. Knain (2005) analysed Weinert's work and concluded that '[o]ne should focus on competences within specific areas rather than general intellectual competences' (Knain, 2005, p. 128, our translation) and therefore ask which competences one needs to meet specific challenges. A relevant question in this paper is which competences chemistry learners in secondary school will need in order to support both present and future actions for sustainable development.

Even though several lists of competences have been given in both sustainability literature (de Haan, 2010; Wiek et al., 2011) and in more general education literature (Voogt & Roblin, 2012), we find that none of them are directly suitable to our model. However, they have informed our task of defining a list of ESD competences. We have, amongst other frameworks, been inspired by the concept of *Gestaltungskompetenz* (de Haan, 2006, 2010). *Gestaltungskompetenz* or 'shaping competence' is linked to being able to shape our society in a sustainable way, i.e. 'to change economic, ecological and social behaviour without these changes merely being a reaction to existing problems' (de Haan, 2010, p. 320). *Gestaltungkompetenz* is developed with a foundation in the OECD's concept of 'key competencies' (OECD, 2005) and can be split into twelve sub-competences. Even though the sub-competences are rather specific, they are of a general educational character and we find them too general to simply transfer them to the chemistry classroom.

Another framework that has been important for our development of competences is the 21st century competences. In a study mapping the diversity of competences for the 21st century, Voogt and Roblin (2012) analysed eight different frameworks for 21st century competences developed internationally. They found that collaboration, communication and social skills were mentioned in all competency frameworks. In addition, creativity, critical thinking and problem-solving were mentioned in most frameworks (Voogt & Roblin, 2012). Gadotti (2008, p. 24) claimed that '[e]ducation for another possible world will be, definitely, an education for sustainability'. Thus, even though the 21st century competences are developed with another purpose than ESD, the competence headings are transferrable to ESD for two reasons. Firstly, both 21st century competences and ESD competences are focused on competences for an unknown future. Secondly, the content of each 21st century heading might be slightly different according to the new context: founded in the chemistry classroom with an emphasis on ESD, the competences might have a different appearance.

Starting out from these frameworks and the question above, we developed a list of nine ESD competences that we consider crucial to support actions for sustainable development. These competences are systems thinking, problem-solving, creativity, critical thinking, action competence, future thinking and belief, normative competence, communication and collaboration. The list of ESD competences emphasises education through science (Holbrook

& Rannikmae, 2007) and our view that chemistry ESD should promote general educational skills (Burmeister & Eilks, 2013b) in addition to chemistry-specific skills. Consequently, some of these competences are chemistry-specific with a distinct origin in the chemistry subject, contributing to chemical knowledge and skills. However, some of them are more centred on general competences that are more relevant outside the world of chemistry education. There is a shift in chemistry education worldwide to emphasise the development of higher-order cognitive skills, aiming to develop graduates who are 'capable of evaluative thinking, decision making, problem solving, and taking a responsible action accordingly' (Zoller, 2004, p. 95). Thus, these kinds of competences should be accounted for in our list – together with the affective aspect of chemical literacy (Shwartz et al., 2006), which is also incorporated in the ESD competences. Each of the nine ESD competences will be described in the following sections.

Systems thinking

Systems thinking can be defined as the ability to 'analyse complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks' (Wiek et al., 2011, p. 207). Systems thinking is therefore considered a key competence to support actions for sustainable development.

In chemistry education, systems thinking is relevant both with respect to understanding scientific working methods and to achieving a holistic understanding of chemistry-related issues. Pupils need to be challenged by systems thinking in order to holistically understand the scientific process of methods, data and conclusions (Kind, 2003). Moreover, systems thinking is crucial in viewing issues from different perspectives. A chemically literate person needs to use his or her chemical understanding as a consumer, in decision-making, in the social debate regarding chemistry-related issues and to understand how innovations in chemistry may affect sociological processes (Shwartz et al., 2006). In chemistry education, a systems thinking perspective may be achieved by investigating environmental, social and economic factors in addition to the chemical content of a specific case. Moreover, the case may be connected to both local and international issues, thereby calling for systems thinking on a global scale as well. Thus, as a part of systems thinking, interdisciplinary and holistic thinking and the understanding of causalities are considered important prerequisites for successfully engaging in sustainability issues (Wheeler, 2000). Due to the complex and pluralistic nature of reality, Rauch and Steiner (2013) urge the need for systems thinking and argue that ESD must not propose a one-sided view; rather, the interdependences between different stakeholders should be recognised and analysed (de Haan, 2010).

Problem-solving

Problem-solving is also frequently emphasised as important in ESD (UNESCO, 2006). We define problem-solving as the ability to solve problems systematically and creatively by assessing the issue or problem, finding and assessing possible solutions and acting upon the solution. Because the chemical industry and research play core roles in finding new solutions for sustainability, chemical problem-solving can be considered especially important. Problem-solving is also important because it practices higher order cognitive skills (Tsaparlis, 2009).

The science classroom has long been acknowledged as an important arena for the development of problem-solving skills in pupils (Garrett, 1987). Good problem-solving skills have also been recognised as a prerequisite for success in chemistry courses. According to Bodner and Herron (2002, p. 235), 'problem-solving is what chemists do, regardless of whether they work in the area of synthesis, spectroscopy, theory, analysis, or the characterisation of compounds'. In chemistry, problem-solving can include theoretical problem-solving exercises that one person may find challenging, but another routine, based on chemical knowledge and experience (Bodner & Herron, 2002). However, the most effective way to develop one's ability to solve problems in chemistry is through practical laboratory work.

Practical laboratory work may have different aims, such as giving the pupils experience in scientific phenomena and related knowledge. Pupils learn *about* science and how science is created. They learn to *do* science and become interested and motivated in the subject through their experiences in the laboratory (Kind, 2003). Furthermore, connecting laboratory work to scientific working methods and working with real-life examples may help the pupils to understand and connect to sustainability issues (Karpudewan et al., 2011).

Although problem-solving is listed as a specific competence in our work, it is a broad term. Closer examination of the definition and the different levels of chemistry reveals that the term implies other competences as well. Being a good problem solver requires creativity in order to develop possible solutions, and results need to be assessed through both systems thinking and critical thinking.

Creativity

Creative thinking refers to '*how* people approach problems and solutions–their capacity to put existing ideas together in new combinations' (Amabile, 1998, p. 79). A future of climate change and major sustainability challenges demands creative citizens who are able to think innovatively and create new solutions. Creativity is therefore regarded as a crucial competency within sustainability education (Daskolia, Dimos, & Kampylis, 2012). Creativity is a crucial part of both chemistry education and scientific working methods. The design of new research questions and models requires creativity (Kind, 2003; Osborne et al., 2003). According to Hodson (1992, p. 546), a chemist requires a special kind of knowledge and understanding that 'combines conceptual understanding with elements of creativity, experimental flair, the scientific equivalent of the gardener's "green fingers" and a complex of affective attributes that provide the necessary impetus of determination and commitment'.

Amabile (1998) claimed that creativity presupposes an interrelationship between three different factors: in order to be creative, a person must first have technical, procedural and intellectual knowledge about the topic (i.e. expertise). Secondly, the person needs to know different ways to approach the problem creatively (i.e. creative thinking skills). Finally, he or she needs motivation–and intrinsic motivation (i.e. a person's internal desire to do something) is more valuable than extrinsic motivation (Amabile, 1998). Thus, creativity is connected to other categories in the model, such as chemical content knowledge and chemistry's distinctiveness and methodological character.

Critical thinking

Critical thinking is a desired goal in science education in general and in assessing sustainability issues in particular. Thus, a clear synergy exists between science education and ESD (Balcaen, 2007). Being able to think critically about issues enables people to examine economic, environmental and social structures while exploring solutions for sustainable development (Tilbury & Wortman, 2004). Critical thinking entails the ability to assess information from both government and lay people. Working with sustainability issues, a lot of the information is of 'the science-in-the-making kind' and may even be 'located at or near the cutting edge of research' (Hodson, 2013, p. 317). Pupils therefore need to assess and detect reliability in information from a variety of sources.

The essence of critical thinking is the quality of thought, not whether the answer is correct (Bailin, 1998; Balcaen, 2007). In ESD, critical thinking can therefore be linked to the ability to consider different perspectives and forms of knowledge in order to describe (non-)sustainable phenomena, to consider information from different perspectives, to evaluate (non-)sustainable actions and patterns of behaviour and to analyse the risk and hazards (de Haan, 2010). Moreover, critical thinking in ESD allows for reconceptualising what ESD needs to be in changing times and contexts (Wals, 2011).

An important aim of scientific literacy is that pupils develop an educational basis for understanding and managing socio-scientific issues (De Vos et al., 2002; Kolstø, 2001). Kind (2003) emphasised the importance of creating a foundation for working with socio-scientific issues through open-ended experiments. During practical experiments, pupils must critically assess research methods and results (Kind, 2003; Kolstø, 2000). Hence, qualities of critical thinking, such as analysis and argumentation, can be developed through practical work. Furthermore, from a scientific literacy perspective, Tal and Kedmi (2006) suggested using everyday relevant issues to engage students in decision-making processes, because pupils need to

> actively interact with social partners, share and communicate in identifying problems, asking questions, constructing and analyzing arguments, judging credibility of sources, interpreting data, hypothesizing, concluding, making value judgments and so forth—all which [are] identified as critical thinking or higher order thinking. (p. 617)

Shwartz et al. (2006) also emphasise the importance of higher-order learning skills within their definition of a chemically literate person. The ability to raise questions, look for and relate to information and analyse the loss or benefit in any debate are the skills they bring forward.

Several scholars also point to the aspect of action as an integrated part of critical thinking (Bailin & Siegel, 2003). According to Siegel, a critical thinker is one who is ‘appropriately moved by reasons’ (Siegel, 1988, p. 23). He emphasised two components of critical thinking: reason assessment and a critical spirit. Hence, critical thinkers must have higher-order learning skills to be able to reason well in order to construct and evaluate solutions. They should be able to follow patterns of reasoning, but they should also be motivated by the critical spirit to act upon them (Cuypers, 2004; Siegel, 1988). Due to this element of action, critical thinking partly overlaps with the next competence: action competence.

Action competence

Rudsberg and Öhman (2010) suggested that one aim of ESD could be to enhance pupils' competence in democratic action. Although *action competence* can be viewed as the final aim of ESD, it is also listed as a distinct competence in our framework. In the question regarding the foundation of the ESD competences, we pointed to competences that support *actions* for sustainable development. This concurs with Mogensen and Schnack (2010), who claimed that action competence is an education ideal that is in line with ESD. Action competence includes 'the capacity to be able to act, now and in the future, and to be responsible for one's actions' (Jensen & Schnack, 1997, p. 175).

According to Kolstø (2000, p. 660), 'science education for action may not necessarily include the action itself. What is important is that the students are trained in articulating and in arguing their views, and in interpreting scientific information in adequate ways'. Jensen (2004) agreed that action competence is developed when pupils are allowed to work with authentic problems, and he presented four dimensions according to which any environmental topic can be viewed and analysed. These dimensions, which also can be used in analysing chemistry-related issues, are as follows:

- Knowledge about effects: What kind of problem is it?
- Knowledge about root causes: Why do we have the problems we have?
- Knowledge about change strategies: How do we change things?
- Knowledge about alternatives and visions: Where do we want to go?

Environmental education is often restricted to the first question, that is, knowledge about the effect. However, including the analysis and understanding of possible visions and changes not only increases the development of action competence, but also contributes to the development of the other ESD competences presented in our model, such as problem-solving, creativity and critical thinking. Moreover, as Jensen (2004, p. 416) pointed out, 'this is particularly important at a time when increasing globalization and individualization is leading to action-paralysis', an observation that leads to the next competence: future thinking and belief.

Future thinking and belief

Jensen and Schnack (1997) emphasised the importance of not instilling anxiety and worry in pupils when discussing environmental problems in the classroom. They called for an emphasis on future thinking and belief. Traditionally, a science-oriented approach to environmental education would emphasise theoretical knowledge about environmental issues and descriptions of increasingly worsening conditions; this could lead to a feeling of disempowerment among the pupils. Instead of inducing this ‘learned hopelessness’ and apathy among the pupils (Nagel, 2005), teaching needs to induce courage, commitment and the desire to solve problems. ESD should not be limited to a pessimistic discussion of global problems. These problems should not be denied, but rather presented as ‘fundamentally manageable [in order to] generate and strengthen young people’s optimism about the future’ (Rauch & Steiner, 2013, p. 14). Thus, an education focused on finding solutions and acting upon these solutions is important. Future thinking and belief is hence very closely linked to action competence.

Future thinking is also an important aspect of the distinctiveness of the chemistry subject. If we think about chemical research and the nature of the chemistry subject, future thinking is very relevant, since research in general demands future thinking. Innovations in chemistry may contribute to finding solutions to different kinds of problems with respect to the environment, health issues and other societal problems. As part of the *Gestaltungskompetenze*, de Haan (2010) emphasised the importance of thinking and acting in a forward-looking manner, both professionally within a future scientific context and personally in the pupils’ own lives. The pupils should be able to

> assess and apply the findings of future research in the drafting of sustainable development processes; . . . recognise their own potential future needs; . . . describe the need for providing a greater social security in the future based on their own situation [and] . . . identify, analyse and assess examples of focusing on the present, starting from their own lives. (de Haan, 2010, p. 322)

In addition, he emphasised the importance of 1) understanding that current actions should be beneficial for future development and future generations and 2) coping with personal dilemmas in decision-making (de Haan, 2010).

Normative competence

Normative competence is yet another crucial competence that pupils develop through ESD (Wiek et al., 2011). Östman and Almqvist (2011) claimed that normative aspects (i.e. norms, values, interests, worldviews and power) must be dealt with in science education in order to foster competent citizenship. As expressed earlier, respect for other human beings is a foundational value in ESD, through which pupils also need to develop solidarity with others and concern for the future of humans and nature (de Haan, 2010). An important aspect of this development is the ability to see multiple sides of an issue and to consider the opinions of other people. Decisions should be both knowledge-based and value-based, which means that during decision-making, the views of all people should be considered, including the antagonists (Kolstø, 2000).

Keywords describing this competence are therefore empathy, solidarity, attitudes and values, all of which should be addressed in school (Eilam & Trop, 2010). Knowing how to respond actively to environmental questions requires being conscious of one's own values and the ability to understand the choices and consequences for those involved (van Marion, 2008). Hence, chemistry education could be an arena for raising such questions, thus stimulating the normative competence of pupils.

Krageskov Eriksen (2002) added to the idea of normative competence through her elaboration on an ethical sphere of chemistry education. She distinguished between ontological knowledge (i.e. knowledge about chemical compounds, concepts and laws), the epistemological sphere (i.e. understanding chemistry as both an activity and a scientific community) and the ethical sphere. The latter 'contains knowledge of chemistry in a social context, including the question of how chemistry is part of society and which (ethical) considerations should be made in this regard' (Krageskov Eriksen, 2002, p. 7). Ethics in chemistry education often involve 'good science', which includes an awareness of issues such as misconduct, fraud, patents, the use of animal and human research subjects, etc. However, ethics in chemistry education should also be connected to societal awareness in both local and global contexts. As Krageskov Eriksen claimed (pp. 9–10), 'ethical reflection in the context of chemical education comes to mean the reflections on the role of chemistry in society and hence on the values underlying this interplay–and, bearing the ideal of reflectivity in mind, the action for adjustment of the values to the social challenges of today and tomorrow'.

Finally, an important part of normative competence is the ability to enjoy the benefits and experience of nature. Sandell and Öhman (2010) pointed to a problematic tendency of ESD: sustainability issues often become anthropocentric and nature is neglected when different interests are considered. Sandell and Öhman therefore stress the value of outdoor education and its ability to widen the scope of ESD as well as awareness of the role of nature.

Communication and collaboration

Finally, communication and collaboration are two interpersonal competences. Pupils need to be able to communicate (verbally, visually and in writing) with other people and clearly express their ideas. Pupils also need to listen to and respect the opinions and feelings of others. Thus, communication is closely connected to the normative competence. Moreover, in chemistry education, the communication of results, controversies, etc. is an important part of the subject.

In addition, pupils have to be able to collaborate with other people, regardless of personalities and backgrounds, in both professional and personal life. Collaboration between people across and within subject areas is important in the research and development of chemical knowledge. Collaboration is also crucial in solving more specific sustainability issues. The increasing complexity of society demands interdisciplinary collaborators rather than lone geniuses (Wagner, 2012). The pupils therefore need to understand and appreciate the fact that collaboration can lead to better end results than individual work, even though the process may be harder. The outcome of collaboration is not only directed towards the product, but also the process where other competences, such as creativity, problem-solving, critical thinking, systems thinking and communication can also be developed. However, effective collaboration must be learned and requires guidance and experience (Blatchford, Kutnick, Baines, & Galton, 2003).

Summary of the ESD competences

In our model, nine competences are considered crucial to support actions for sustainable development: systems thinking, problem-solving, creativity, critical thinking, action competence, future thinking and belief, normative competence, communication and collaboration.

The list of ESD competences is not finite. Developing competences is viewed as an ongoing, lifelong process of learning (Rychen & Salganik, 2000). The importance of different competences varies across regions of the world according to cultural norms, technological access and social and power relations (OECD, 2005). Views of 'relevant' learning outcomes also depend on context (de Haan, 2010; Knain, 2005). However, a main aspect of the concept of competences is the ability to transfer competences from one situation and use them in another setting (Kauertz et al., 2012). Our list of competences has, therefore, a foundation in chemistry education, but is thought to cover situations pupils also need outside the chemistry classroom. The aim has been to identify competencies that are broad enough to cover different aspects and nuances of ESD, but at the same time precise enough for teachers to focus on, one or more at a time, when chemistry lessons are planned and evaluated. Similar to Holbrook's (2005) concept of education through chemistry, the chemistry classroom can be an arena for pupils to develop ESD competences while they acquire knowledge about chemistry; this can lead pupils towards self-regulated learning (Gräber, 2000).

Lived ESD

The last ellipsis in our model outlines how ESD principles are realised in classroom and school cultures, providing pupils with an opportunity to experience sustainable living. Lived ESD is situated in the outer ellipsis of the model indicating that this category influences all educational experiences, both within the chemistry classroom in particular and in the school culture in general.

Teachers can be influenced to focus more on ESD if an ESD school culture is established at the school. An ESD school culture is characterised by a respect for the environment and democratic principles. Sterling (2009) describes sustainable schools as schools where collaboration, flexibility and trust are important; where diversity is valued and where everyone is treated with respect. In a sustainable school culture, the principles of sustainability also extend to school management. Examples could include energy-saving measures as well as facilities for sorting waste, ecological food and school gardens. The effectiveness of these small energy contributions on the global environment may be questionable, but as Jensen and Schnack (1997) pointed out, the crucial factor is what the pupils actually learn from participating in such activities. By engaging in such activities and experiencing how sustainability is realised at the school-level, pupils should begin to learn how to live sustainable lives (Sterling, 2009).

Although our framework is directed towards the chemistry classroom and not school management, such measures of sustainability by the school could influence the chemistry classroom and the perception of the role of the teacher in the classroom. Indeed, classroom culture reflects the culture of the school and its values. However, classroom cultures can also affect the school culture if the particular classroom culture is spread to other classrooms (Bronfenbrenner, 1994).

The teacher plays a major role in establishing a classroom culture that corresponds with the principles of ESD. Borg et al. (2012) investigated teachers' subject-bound differences in realising ESD. They found that teachers were strongly influenced by their own education and that they were likely to build their understanding of sustainable development on the foundation of the traditions they had experienced through their studies. Science teachers hence tended to be oriented towards the fact-based teaching tradition, instead of a pluralistic teaching tradition, which acknowledges different perspectives, views and values (Borg et al., 2012). This might raise a specific challenge for science teachers with respect to realising ESD and their choice of teaching strategies. Teaching should move away from what Jickling and Wals (2013, p. 78) call ‘big brother sustainable development’, in which the view of education is instrumental and deterministic, and towards a socio-constructivist and transformative view about education which in turn would be more emancipatory. In order to achieve such a change in pedagogy, teacher education in ESD is essential mainly because a reform in teaching practice must begin in the teacher education programme (Burmeister & Eilks, 2013b).

The role of the teacher is not only choosing an appropriate pedagogy. The teacher is important as a role model as well, and can, according to Hungerford and Volk (1990), have a significant influence on pupils’ thinking in relation to the environment. The teacher also has a significant role in creating a friendly, empowering and safe learning environment. Within this learning environment, the same emphasis on collaboration, flexibility, trust, respect and diversity should be acknowledged (Sterling, 2009).

The elements of lived ESD discussed in this section are relevant also to the lives of the pupils outside school. As a part of lived ESD, we can cross school borders to connect social sustainability and democracy to the surrounding society. Through the linking of chemistry content to specific local contexts and locally relevant sustainability issues, pupils may be assisted in understanding their local community and its related issues – further serving to encourage community engagement. We can also make a linkage between the chemistry classroom and the chemical industry (Hofstein & Kesner, 2006), as discussed earlier in this paper.

Elaborating and Clarifying the Elliptic ESD Model as a Model for Teaching and Learning

In this paper, we discussed how chemistry education could become an arena for ESD. We have already introduced the elliptic model of ESD in chemistry education (Figure 1). The model consists of five ESD categories, all represented by an ellipsis. The three central ellipses of the model are strongly connected to the subject of chemistry, whereas the remaining two ellipses have a more general educational character. Figure 2 shows a comprehensive version of the same model, including sub-categories of each ESD category. The five ellipses in the model visualise the different levels of the five ESD categories and exemplify how the ideas that underlie the elliptic model could be realised in chemistry education. Even though ESD has a diverse and multidimensional nature and the ESD categories are intertwined, they can be realised in chemistry education and thought about as different ‘layers’. This emphasis on the different layers will allow teachers to introduce ESD gradually and to scatter it throughout their teaching. The model is also relevant and adaptable within different contexts. A change of context may alter the content of the ESD categories and the priority of the sub-categories, but the model will still be applicable.

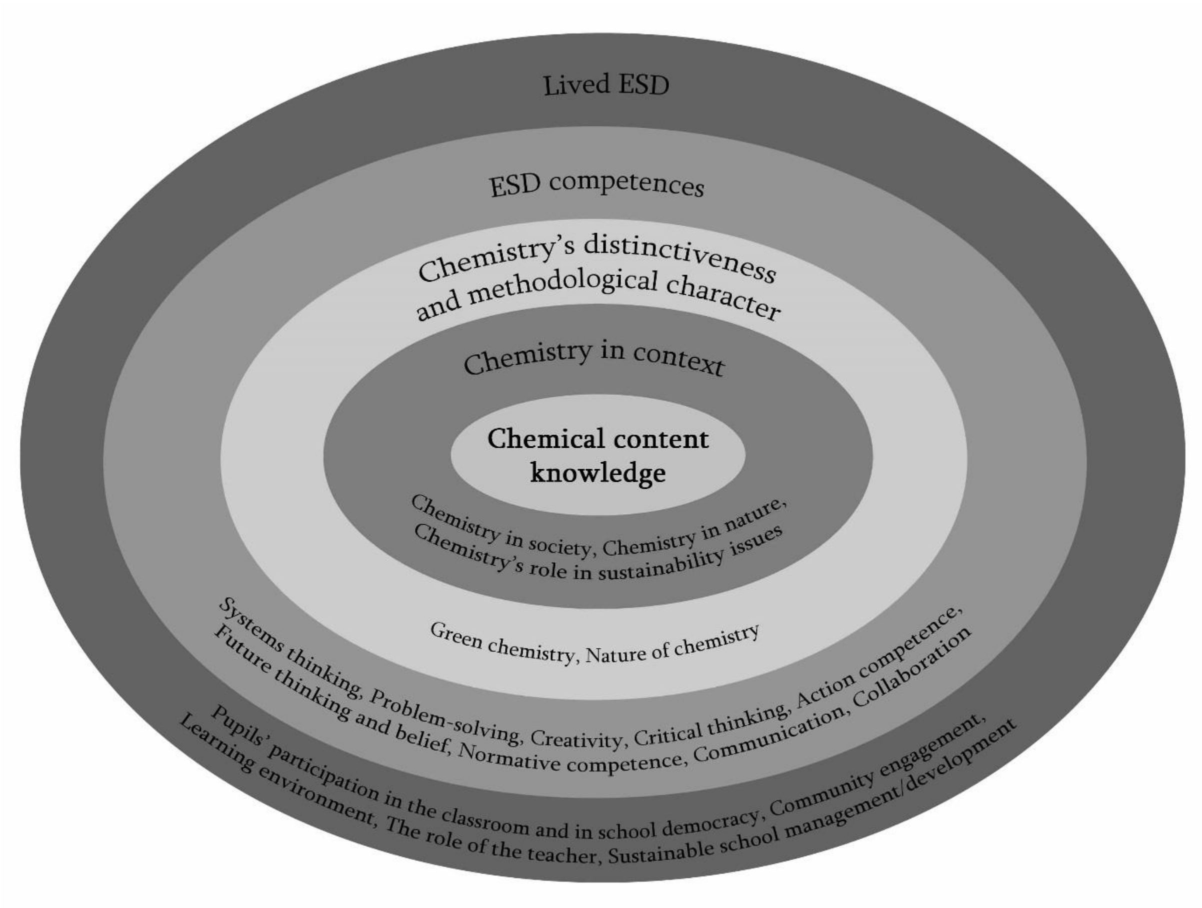

Figure 2. The elliptic model of ESD in chemistry education: a model for planning and analysing chemistry education for sustainable development

At the centre of the elliptic model of ESD is chemical content knowledge. The content knowledge is centred in the middle because this is where a secondary school teacher usually would start his or her educational planning, deciding what the chemical topic of the lesson should be. The choice of topic would generally be based on curricula, annual plans and other leading documents. Chemical content knowledge can comprise either direct knowledge about sustainable development issues or background knowledge that can be situated in various contexts, thus linking the content knowledge to sustainable development. On the other hand, many issues and topics taught in the chemistry classroom will not be connected to sustainable development. Nevertheless, through the elliptic model, we want to show that regardless of sustainability focus, the chemistry classroom may be an arena for ESD simply by focusing on the other ellipses in the model, hence the previously mentioned aim of bridging the gap between the school and ‘an ideal and sustainable world’.

Continuing outward in the model, we find chemistry in context. Situating the subject within a context is especially important in ESD and can be done regardless of the sustainability focus. After the content of the lesson is chosen, selection of context would be a reasonable next step. Typical questions for the teacher to ask are: Can the content be made relevant for the pupils by connection to a context that is familiar? Can the content be linked to a sustainability issue? Should this topic be taught in an outdoor environment? The subject in connection to nature and/or society will not only increase the relevance of the subject for pupils, but also lead them to practice systems thinking and other competences. This is just one example of the overlapping and holistic nature of the model. If the context is related to a sustainability issue, light will also be shed on the specific sustainability issue and pupils may develop both knowledge and personal concern about the issue.

Chemistry’s distinctiveness and methodological character emphasises green chemistry and the nature of chemistry. This can be enhanced through practical work connecting the three levels of chemistry–the microscopic, sub-micro and symbolic levels (Johnstone, 1991)–and through real-life issues. By consciously reflecting on green chemistry principles and the nature of chemistry, pupils may increase their understanding of the scientific process in chemistry in particular and in science in general.

The next ellipsis is ESD competences. ESD competences may be the foundation of all working methods of teaching and learning. Regardless of topic and context, the teacher could emphasise the development of specific ESD competences in all pupils. Thus, having a conscious focus on selecting teaching and learning methods would contribute to the development of these competences. Pupils will have different needs depending on age and individual differences, and development of one competence must therefore occur gradually and in a planned manner. Hence, a strategy with respect to the development of the ESD competences is suggested.

Finally, in the outer ellipsis of the model, we find lived ESD. Lived ESD could be considered a frame within which the other ESD categories lie, as illustrated by the position in the elliptic model. The category includes ESD keywords such as social sustainability and democracy; social sustainability offers the pupils a friendly and safe learning environment both in the classroom and at each school level and democracy is connected to pupil participation. Thus, the category involves both the role of the teacher in creating a friendly and safe learning environment (characterised by ESD principles) and the importance of a sustainable school culture. Lived ESD is emphasised as a part of the general education in schools, but is also transferable to the lives the students live outside school.

A challenge often experienced within ESD is maintaining a balance between subject-specific and general ESD perspectives. A limitation of ESD models, as in much interdisciplinary work, may be that the model is either too oriented to chemistry (i.e. too specific) or is too general. A model that is too general may suffer from the lack of approval by teachers because it might subsume the subject of chemistry. Furthermore, the application of the model could compete with the objectives of the curriculum. On the other hand, a model that is too chemistry-oriented risks being limited by the fact-based teaching tradition, thus failing to meet the goals of general education necessary in ESD. Hence, the chemistry education could fail to contribute to the preparation of responsible citizens, which is an aim of ESD. In our model, the balance between three subject-specific ellipses and two ellipses that are oriented towards general education attempts to prevent such limitations. Thus, teachers can see the two outer ellipses as the foundation of all chemistry-oriented teaching and learning activities to educate for sustainable development through the subject of chemistry.

For many teachers, emphasising ESD competences and lived ESD would be a good way to begin realising ESD in their teaching. This especially accounts for curricula that are not explicitly oriented toward ESD. The model can still be applied in these settings through a conscious focus on green chemistry, the nature of chemistry, connecting the subject to a relevant context, emphasising different competences in an education through science perspectives and fostering a classroom atmosphere characterised by lived ESD. Furthermore, to achieve the holistic ESD perspective, examples relevant for sustainable development should be included when appropriate. Most chemistry topics (e.g. equilibrium, acids and bases, electrochemical reactions, etc.) need to be taught within a context, and the teacher therefore has great influence when it comes to selection of examples and thereby context.

Conclusion

The ESD model presented in this paper provides a perspective from which to develop a sustainable chemistry education within the current chemistry curriculum. Overloaded subjects are one of the challenges teachers point to when attempting to realise ESD in their classrooms. This model therefore presents a way to realise ESD in chemistry education without adding more content knowledge to the curriculum. The elliptic model of ESD in chemistry education is developed in order to support teachers in their realisation of ESD and could therefore be presented during in-service and pre-service teacher education programmes.

Introducing a model such as the elliptic ESD model is, however, not enough to enable the teachers to educate for a sustainable development. They also need adequate education in order to realise the specific sub-categories. Moreover, the teachers must prioritise the different categories and sub-categories of this model; further, we have emphasised the significant selection of content, context, examples and pedagogy. Facilitation for teachers to realise ESD is also the teachers' desire to actually realise ESD in their future classrooms (Scott, 1996). All these perspectives must therefore be addressed in teacher education aiming at ESD.

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Science teacher education for sustainable development: from intensions to realisation

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Abstract

Teacher education programs have an especially important role in reorienting education to realise education for sustainable development (ESD). In this paper, we investigate how ESD can be realised in science teacher education and we present findings from a case study in a Norwegian teacher education institution that has the overall aim of educating teachers who can contribute to sustainable development. Data was collected through participant observations and interviews, and, together with instructional artefacts and student assignments, analysed based on a model for science ESD. The paper provides an example of how ESD can be realised through a strengths approach where ESD is founded in the strengths among the teacher educators and existing teaching practices. The results indicate that an emphasis on experiential learning and sociocultural learning theory builds a thorough foundation for ESD. However, the teaching has to be explicit in order to reach all student teachers.

Introduction

The teachers of today are educating the future leaders and citizens of the world; they therefore play an important role in education for sustainable development (ESD) (Hopkins & McKeown, 2002). However, several studies have found that teachers struggle to realise ESD in their teaching (Burmeister & Eilks, 2013; Burmeister, Rauch, & Eilks, 2012; Sinnes & Jegstad, 2011). One of the challenges teachers face with respect to the realisation of ESD has been identified as the inclusion of even more content into an already overloaded curriculum. It has therefore been suggested that ESD be integrated as a perspective applied across the content in all existing subjects (Jegstad & Sinnes, 2015; Rudsberg & Öhman, 2010).

ESD has been on the political agenda in the past decades, especially through the United Nation's decade of ESD (UNESCO, 2005) and thereafter the Global Action Programme (UNESCO, 2016). The ability and capacity to realise ESD at school level depend on teachers' knowledge and beliefs about both the subject matter and pedagogy. Thus, teacher educators play an important role in facilitating the development of student teachers' professional understanding and practice within ESD (Corney & Reid, 2007). The purpose of this study is to investigate how a teacher education institution with the overall aim of educating teachers who can contribute to sustainable development includes such practices in its science teacher education program. ESD as an overall aim of teacher education is rare in the research literature and the paper therefore provides insight into a previously little researched area.

The importance of teacher education programs in preparing their student teachers to realise ESD in the classroom has been acknowledged for several decades (Scott, 1996). Borg, Gericke, Höglund and Bergman (2012) investigated subject-bound differences among teachers in realising ESD and found that they were strongly influenced by their own subject tradition from their own higher education and teacher education programs. For science teachers, this meant that the teachers tended to be oriented towards the fact-based teaching tradition, where environmental issues are seen as knowledge problems which can be solved by carrying out more research and informing the public (Rudsberg & Öhman, 2010). However, a content focus on the problems of today's society is not enough to achieve a sustainable future; one also needs a general education in societal participation (Burmeister & Eilks, 2013; Wals, 2011). A teaching tradition in line with ESD principles would be more pluralistic and acknowledge different perspectives, views and values (Borg et al., 2012). These findings point to the specific challenges for science teachers with respect to the realisation of ESD, which in turn raises challenges for science teacher education programs.

The research question explored in this paper is *how can ESD be realised in science teacher education?* The research question is investigated by analysing the case of a teacher education program in Norway and will be answered based on two auxiliary research questions; *how is ESD realised in an ESD-oriented science teacher education program* and *how do the student teachers in the teacher education program demonstrate their understanding of ESD?*

An ESD model for planning and analysing science ESD (Jegstad & Sinnes, 2015) was used in the analysis. This model will be presented in the next section, together with the theoretical perspectives that the paper builds on. The result section is guided by the auxiliary research questions, which will then be further called upon to answer the main research question. Both the actual realisation of ESD and how the realisation can be improved will be discussed.

Theoretical perspectives on ESD in science teaching and learning

ESD is about preparing the younger generation to become *'responsible citizens'* (Burmeister et al., 2012, p. 59), i.e. citizens with respect for other human beings (both present and future generations) and for the planet and what it provides (e.g., resources, flora and fauna). This responsibility is connected to both action and decision-making (Summers, Childs, & Corney, 2005), and raises challenges for teacher education programs. They have to help student teachers to realise ESD within a school system, where subject requirements are of central interest. New demands are placed on the selection of content, processes and the context, and student teachers need a clear rationale for the use of different teaching and learning strategies, as well as support in the actual ESD.

According to Hopkins and McKeown (2002), the most realistic way to realise ESD globally is through a '*strengths model*', where the approaches towards ESD are adapted to the context and the strengths among the educational labour force:

> Once the concept of sustainability is broadly understood and the need to reorient education is accepted, the way forward will be greatly enhanced by combining the contributions of traditional disciplines and the experience and creativity of current teachers and administrators. (Hopkins & McKeown, 2002, p. 22)

Moreover, support for the actual realisation is also needed and we therefore published a theoretical model for planning and analysing science ESD (Jegstad & Sinnes, 2015). The model acknowledges that the subject, with all its curricular demands, has a distinct role, but by focusing on *education through science* (Holbrook, 2005) – where the emphasis is on how general educational skills may be promoted *through* the subject of science –, the other elements of ESD can be realised. Figure 1 presents the model, which consists of five categories, illustrated through five ellipses. Within each category, there are sub-categories that specify the content of the ESD categories.

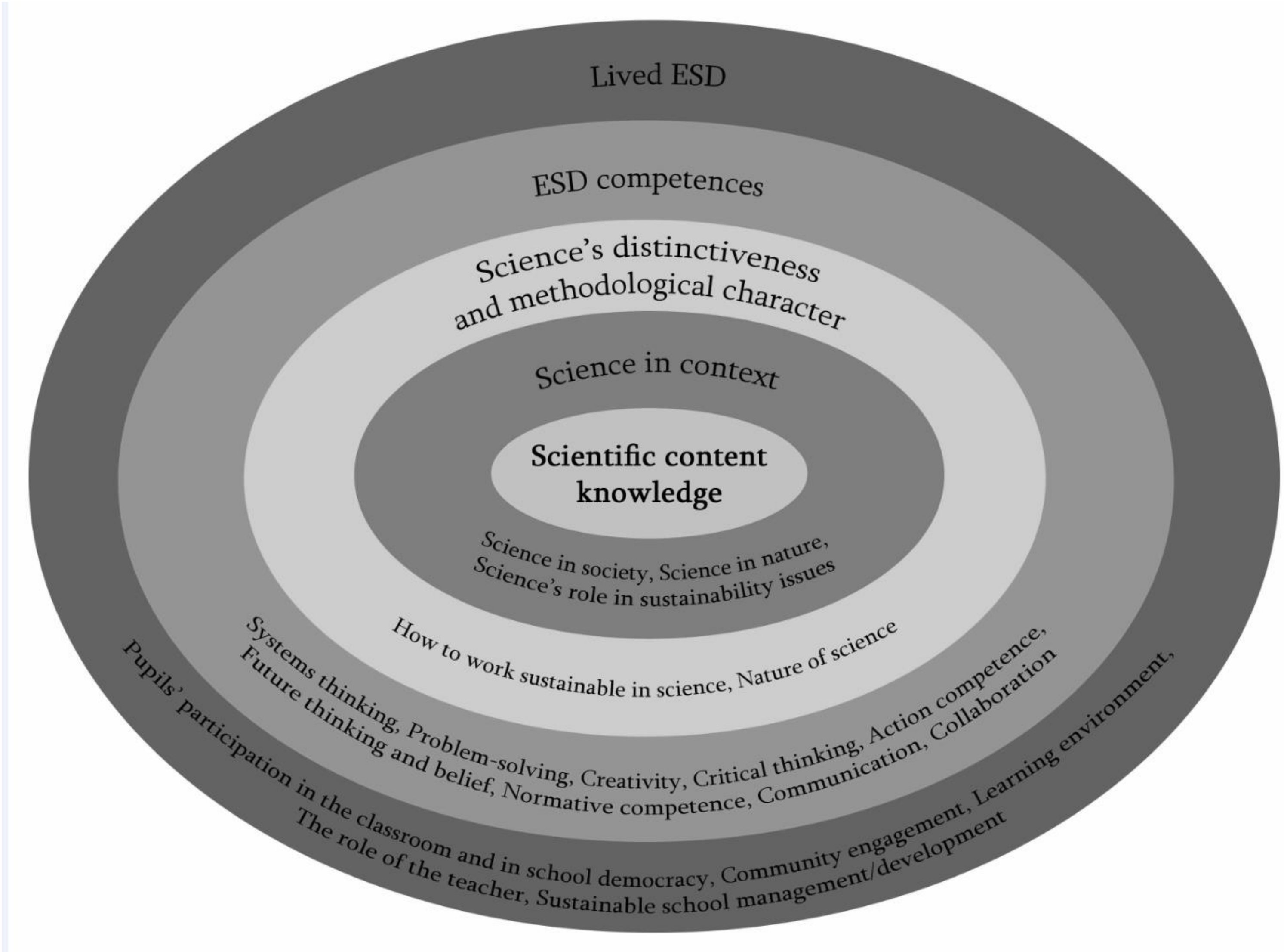

Figure 1. A model for planning and analysing science ESD (Jegstad & Sinnes, 2015)

The central ellipse, *scientific content knowledge*, covers content knowledge that is relevant for sustainability, including background knowledge (Jegstad & Sinnes, 2015). However, regardless of the sustainability focus in the content knowledge being taught, the science class may be an arena for ESD simply by emphasising other ellipses of the model.

Situating the subject within a *context* is especially important in ESD, and this can be done for all topics. Dillon (2012) pointed to the mutual benefits of linking the content to a sustainability context, as pupils would become more interested in learning science in conjunction with a specific sustainability issue. Further, the third ellipse, *the subject's distinctiveness and methodological character*, is enhanced through emphases on the nature of science (NOS) and the sustainability practices within the specific scientific discipline, e.g. green chemistry (Karpudewan, Hj Ismail, & Mohamed, 2011; Ware, 2001). NOS is connected to the influence of the scientists and how they make generalisations and theory based on scientific inquiry, which emphasises the importance of understanding scientific research methods. It also includes the tentative and uncertain nature of scientific knowledge (Lederman & Lederman, 2012).

The *ESD competencies* listed in Figure 1 may be the foundation of all working methods regardless of the topic and context, and the emphasis is on the ESD competencies that may be promoted when participating in science-related activities (Jegstad & Sinnes, 2015). The concept of ESD competencies has been emphasised by scholars in the field of ESD (de Haan, 2010; Jegstad & Sinnes, 2015; Rauch & Steiner, 2013; Voogt & Roblin, 2012; Wiek, Withycombe, & Redman, 2011) and includes the competencies of systems thinking, problem-solving, creativity, critical thinking, action competence, future thinking and belief, normative competence, communication and collaboration.

Finally, the placement of *lived ESD* in the outer ellipsis illustrates that principles from this category can be the foundation for everything that happens at school, both in the classes in particular and in the school in general. Hence, lived ESD can be considered a frame in which the other ESD categories lie, and it offers the pupils a friendly and safe learning environment. In sustainable schools, collaboration, flexibility and trust are important, diversity is valued and everyone is treated with respect (Sterling, 2009).

The ESD model was originally developed with secondary schools in mind, and four out of five ellipses do therefore focus on the pupils and what they need to know or be able to do. The focus in lived ESD is, on the other hand, divided between pupils (in community engagement), the teacher (in pupil participation, learning environment and the role of the teacher) and the school as organisation (in sustainable school management/development).

All categories had a distinct meaning within the secondary school context. This meaning was further developed within the context of the science teacher education program when the student teachers were prepared for ESD. Thus, even though the sub-categories were developed in advance, their meanings were expanded in the context based on the ESD construction in the teacher education program. We will return to this ESD construct in the discussion section of the paper.

Methodology

According to Corcoran, Walker, and Wals (2004), a case study is an appropriate research tool for studying sustainability in higher education due to the flexible and adaptive nature of the methodology. It is further applicable when explanatory questions, such as 'how' and 'why' questions, are posed (Yin, 2009).

In the study, a one-year teacher education program for candidates with an academic or vocational educational background in science, mathematics and/or agriculture constituted the case. The teacher education program amounted to 60 ECTS credits (one-year full-time study) and the student teachers attending the science teacher education program already possessed a Bachelor's, Master's or doctoral degree in a scientific subject. The program was organised through twelve, week-long modules; six of these modules were in science education while the remaining six were in pedagogy. The student teachers also carried out twelve weeks of practical training in schools and four major mandatory assignments: two individual assignments in science education, one individual assignment in science education and pedagogy (combined) and one group assignment in pedagogy.

The research has been carried out in our own organisation. The first author has been in charge of the data collection and analysis. She was a student teacher in the teacher education program before ESD became the overall aim, and has throughout the research period contributed in some teaching sessions and guided some student teachers. Both the second- and third authors have been working in the teacher education program for more than a decade and have contributed strongly in the development of the ESD expression.

Data collection

The case was followed over consecutive years (2010, 2011 and 2012) and the paper builds mainly from data from the academic year 2011/2012. Data has been collected widely in order to gain a deep understanding of the realisation of ESD in the teacher education program. We carried out participant observations in both meetings which involved planning the teaching sessions and in the actual teaching sessions, and interviews. The data corpus also included instructional artefacts such as handouts, presentations and other documents available to the student teachers, documents related to meetings in the teacher education institution and various assignments.

In order to analyse *how ESD was realised in the teacher education program*, we analysed relevant teaching sessions in the six science education modules, the six pedagogy modules and the general perspective of the teacher education program. The general perspective covered activities and aspects that were not visualised in the analysis of the specific modules. This included logs (a tool that is widely used in the teacher education program to increase the ability of the student teachers to reflect); student democracy; the learning environment and social aspects of the teacher education program; and topics that were outside the teaching modules such as practical training. Hence, in the general perspective, we analysed aspects of the teacher education program that was present throughout the year, across the specific modules.

The relevant science education sessions were chosen based on our knowledge from the observations of the sessions and participation in meetings planning these sessions. When doubt occurred as to whether a session was relevant or not, the session was nevertheless included in the analysis. We also included the pedagogy modules in the analysis, since we found the ESD expression in the science teacher education program to be dependent on both the science education and pedagogy modules. The data used in the analysis is listed in Table 1.

Table 1: List of data material used to analyse the realisation of ESD in the teacher education program

Data
Schedules of each of the 12 teaching modules with information letters describing the modules
PowerPoints and memos handed out in the teaching sessions analysed
Sound recordings from semi-structured interviews with four teacher educators and from a focus group conversation with four teacher educators about ESD in the pedagogy modules
Participant observations of teaching sessions
Participant observations and sound recordings from meetings planning the teaching sessions
Reflection notes written by the first author
Reports from meetings and documents handed in as participant preparation for meetings
Curricula for the teacher education program (national and local curriculum for the teacher education program and the local curriculum for the practical training)
Report from the external evaluation of the teacher education programs and a self-report written as preparation for the external evaluation (one study program at the university is evaluated each year and in 2012, the teacher education program was the subject of evaluation)

To explore *the student teachers' understanding of ESD*, we analysed the data material listed in Table 2. Our main emphasis in this analysis was on the student teachers' assignments written during the spring of 2012 and it included both the science education assignment and the combined assignment in science education and pedagogy. ESD was not a given topic in any of the assignments, but the student teachers' assignments play a major role in the teacher education program and they aim to develop the student teachers as future teachers (Gjøtterud, 2011). We also found the assignments to be good indicators of what the student teachers' main interests in education were.

Table 2: List of data material used to analyse the student teachers' understanding of ESD

Data
Student evaluation schemes
36 science education assignments written towards the end of the teacher education program, where the students chose an issue within science education to discuss and experiences from the practical training were linked to educational theory
19 exam preparative assignments, where the science students reflected on their development as teachers
17 exam preparative assignments, where the combined science and agriculture students and the combined science and mathematics students reflected on their development as teachers

The teacher education program has both full-time and part-time student teachers. The part-time student teachers attend modules in science education in the first year and modules in pedagogy in the second. Hence, only the exam preparative assignments of the full-time student teachers were analysed and we analysed 19 assignments – compared to 36 science education assignments.

Data analysis

All data was analysed according to the research questions using *meaning categorisation* (Kvale, 1996). The categories used were the 18 sub-categories of the ESD model (Jegstad & Sinnes, 2015).

The six science education modules were analysed session by session. We analysed in total 30 sessions from the science education modules. In the analysis, we differentiated between the levels of inclusion of each sub-category that was identified: slight emphasis (the topic was not focused upon explicitly or the topic was in force through collateral learning) or emphasised. Thereafter, a holistic ESD expression of each module was summarised. In the summarised results, we operated with four levels of inclusion of the sub-categories: 1 = not covered; 2 = partly covered (1–2 sessions/module); 3 = partly emphasised (2–4 sessions/module); and 4 = recurrent emphasis (the majority of the sessions). There are no fixed boundaries in these levels, as both the length of each session and the level of inclusion (i.e. slight emphasis or emphasised) of the sub-categories in each session varied. Thus, the summarised ESD expression of each module was evaluated separately.

On the other hand, each pedagogy module was analysed as an entity, as most sessions within a module were within the same topic. These modules were therefore directly analysed with the use of the four levels. The same applied for the general perspective of the teacher education program. The results of the analysis are listed in a table, followed by a presentation of the ESD expression, including translated quotes from teacher educators responsible for the topic.

In the analysis of the assignments, the emphasis was on the inclusion of the categories from the ESD model. The student teachers did not necessarily discuss ESD as a concept in the assignment, but they had to explicitly describe and discuss elements from the model for it to count in the analysis: 21 out of 36 science education assignments and 18 out of 19 exam preparative assignments followed this criterion and only these assignments are included in the diagrams in the result section of the paper. In the diagrams, we have differentiated between the levels of inclusion of each sub-category that was identified: slight emphasis or emphasised. The result section also includes translated quotes that are found to be especially illustrative with respect to the student teachers' perception of the ESD categories. We have included quotes from both student teachers who showed a particularly well-developed understanding of ESD and from the more typical assignments. The names used in these excerpts are pseudonyms.

The strength of a case study lies in the variety of empirical material that can be used in the analysis (Yin, 2009) and in the possibility of triangulation. The data from this case study was triangulated in two steps: firstly, data from different sources of informants and documents were combined in order to corroborate the analysis of the sessions of the teacher education program. Secondly, data from the perspectives of the teacher education program, the teacher educators and the student teachers was triangulated in order to corroborate the analysis of the teacher education program as an entity. Triangulation has thus contributed to the validity of the research project (Flick, 2004) and thorough documentation of the research procedures has contributed to the reliability (Kirk & Miller, 1986).

Results

How is ESD realised in the science teacher education program?

The teacher educators articulated the overall aim after realising that ESD was a topic of common research interest. They followed up on the aim by investigating how their own practices and research interests could be used in order to realise ESD in the teacher education program. The realisation of ESD in the teacher education program found in the analyses is presented according to the ESD model and the four levels of inclusion in Table 3 below. Each teaching module is presented separately, while the final column illustrates the general perspective of the teacher education program that is not covered in the analysis of the specific modules.

Table 3. Realisation of ESD in the teacher education program

Cat	**Sub-category**	Teaching modules												**GEN**
		$M1_{SE}$	**$M2_{P}$**	**$M3_{SE}$**	**$M4_{P}$**	**$M5_{P}$**	**$M6_{SE}$**	**$M7_{SE}$**	**$M8_{P}$**	**$M9_{SE}$**	**$M10_{P}$**	**$M11_{P}$**	**$M12_{SE}$**	
CK	Content knowledge	dark grey	white	dark grey	white	white	white	white	white	light grey	white	white	white	white
SiC	Science in context	dark grey	white	black	white	white	white	black	white	black	white	white	dark grey	black
SD&MC	Nature of science	white	white	dark grey	white	white	light grey	light grey	white	black	white	white	white	white
	How to work sustainably in science	white	white	light grey	white	white	white	white	white	white	white	white	white	white
ESD competencies	Systems thinking	light grey	white	dark grey	white	white	white	dark grey	light grey	light grey	white	white	white	white
	Problem-solving	white	white	black	dark grey	dark grey	white	dark grey	dark grey	white	white	white	light grey	dark grey
	Creativity	white	light grey	dark grey	light grey	light grey	white	dark grey	white	white	white	white	dark grey	dark grey
	Critical thinking	white	white	dark grey	white	white	white	dark grey	white	dark grey	white	white	dark grey	white
	Action competence	white	white	black	dark grey	dark grey	white	white	black	white	light grey	black	white	dark grey
	Future thinking and belief	black	white	dark grey	light grey	white	white	white	white	white	white	white	white	light grey
	Normative competence	dark grey	dark grey	black	dark grey	white	light grey	light grey	dark grey	white	black	dark grey	dark grey	black
	Communication	white	black	black	white	white	light grey	light grey	dark grey	light grey	light grey	dark grey	white	dark grey
	Collaboration	light grey	black	black	black	black	dark grey	light grey	black	white	dark grey	dark grey	light grey	black
Lived ESD	Pupil participation	light grey	light grey	dark grey	light grey	dark grey	light grey	dark grey	light grey	light grey	light grey	light grey	light grey	black
	Community engagement	dark grey	white	black	light grey	light grey	white	dark grey	white	dark grey	white	light grey	light grey	dark grey
	Learning environment	black	light grey	black	dark grey	black	light grey	white	white	white	light grey	light grey	white	black
	The role of the teacher	black	black	black	black	black	black	black	black	black	black	black	black	black
	Sustainable school management/development	white	white	white	dark grey	black	white	white	black	white	white	dark grey	light grey	white

Colour codes: white = not covered; light grey = partly covered (1–2 sessions/module); dark grey = partly emphasised (2–4 sessions/module); black = recurrent emphasis. Each module is presented as a number and the subscript of the module heading illustrates whether the module was in science education (SE) or pedagogy (P).

The analyses showed a recurrent emphasis on science in context and the ESD competencies of problem-solving, action competence, normative competence, communication and collaboration. Lived ESD was also largely emphasised, while NOS and the ESD competencies of systems thinking, creativity and critical thinking were addressed to some extent. In the following, we present the elements which contributed to the ESD expression in the teacher education program. The presentation will be related to the categories of the ESD model.

Scientific content knowledge

Due to the student teachers' scientific background (they all possessed a science degree), scientific content knowledge was not emphasised in the teacher education program. There were only a couple of lectures focusing on content knowledge, for example on the first day of the program, when attention was brought to ESD and the overall aim of the teacher education program through a lecture covering topics such as peak-oil, phosphorous deficiency, land protection, fuel sources and renewable energy sources. Otherwise, most content knowledge was introduced through collateral learning (Dewey, 1938), which is what one learns through and by doing other things, for example when the student teachers also learn about a specific topic when the purpose actually was to practice a specific teaching method.

Science in context

The ESD expression in the teacher education program was evident in the pedagogical principles and working methods of the teacher education program, i.e. sociocultural learning theory (Lave & Wenger, 1991; Vygotsky, 1978) and experiential learning theory (Dewey, 1938). The pedagogical foundation of *experiential learning* led to a specific focus on context-based teaching and learning, and an emphasis on how the student teachers could make the societal relevance of science explicit in their teaching. For example, a residential field course was included at the beginning of the academic year in order to prepare the student teachers for outdoor classes.

Founded in experiential learning, self-regulated learning (Gjøtterud, 2011) and learner-active teaching approaches, such as *phenomenon-based teaching* and *inquiry learning*, were also emphasised in the teacher education programme. Phenomenon-based teaching (Dahlin, Östergaard, & Hugo, 2009) is an inductive teaching approach, where theory is introduced to the learners after they have been exposed to a phenomenon (something perceptible). An example of how this was included in a teaching session was described by a teacher educator in an interview:

> In a teaching session, a piece of charcoal was placed on one side of a long table and a green leaf was placed on the opposite side. This illustrated the story of the carbon cycle. The student teachers built the bridge together with the teacher educator – from the charcoal to the green leaf. I could not imagine a larger story.

When asked about how phenomenon-based teaching contributes to ESD, the same teacher educator pointed to the importance of affection:

> Affection is, from my perspective, the most meaningful approach to the relationship between ESD and phenomenon-based teaching. Our senses may be developed if we are affected by nature through being in it. Observing alpine plants affects me, because these small plants are so powerful. ESD presupposes that we are caring for the things we want to protect.

In order to link phenomenon-based teaching to the school subjects, the student teachers were encouraged to use *the reverse curriculum approach* (Bergli & Myren, 1999); they start out from the phenomenon and analyse the potential learning outcomes by engaging in the phenomenon or assignment.

Inquiry learning was also strongly applied. Inquiry learning is related to methods that support the pupils in learning about scientific inquiry and in developing knowledge of science concepts and NOS through an inquiry process (Crawford, 2014), and it was to a large extent linked to complexity and socio-scientific issues (SSIs) (Kolstø, 2001). The student teachers were also encouraged to work with their own subjects in order to develop teaching examples using inquiry learning.

Science's distinctiveness and methodological character

The ESD category *science's distinctiveness and methodological character* was addressed through an emphasis on the process dimension and the development of the student teachers' understanding of NOS. Pupils' understanding of NOS is important for decision making in the pupils' lives, especially within topics linked to SSIs (Kolstø, 2001). NOS was emphasised through inquiry learning, but was also treated as a separate element. How to work sustainably within the scientific discipline was, on the other hand, scarcely covered.

ESD competencies

Within ESD competencies, the analyses had a dual focus: how the student teachers were aware of and developed their own ESD competencies – and how the student teachers learned to facilitate the development of ESD competencies among pupils. The latter was linked to the working methods applied in the teacher education program, for example through the focus on inquiry learning, which facilitated the development of specific ESD competencies: *problem-solving* and *creativity* in answering the issue raised; *systems thinking* and *critical thinking* in order to assess the results; and *collaboration* and *communication* since inquiry tasks are often given to groups of learners.

Sociocultural learning theory emphasises the importance of a social community and collaboration as a part of teaching, learning and knowledge-building. The teacher education program contained much group work and the student teachers were also introduced to and experienced some distinct tools for learning collaboration. Through a pedagogical development project, the student teachers did not only experience collaboration, but also action. The ability to change a system is important in ESD, and through this project, where the student teachers had to actually do something, they may develop *action competence*. Action competence is 'the capacity to be able to act, now and in the future, and to be responsible for one's actions' (Jensen & Schnack, 1997, p. 175), and according to Mogensen and Schnack (2010), an educational ideal in line with ESD.

In the final science education module, a major part of the module was devoted to a discussion on the different ESD competencies; the student teachers discussed why the competencies were important to develop in order to contribute to sustainable development and how the competencies had been addressed throughout the teacher education program.

Lived ESD

Whereas the other categories have the knowledge, skills and competencies of the pupils in mind, Lived ESD is more focused on how the teacher facilitates for the pupils' experience of ESD. The sociocultural perspective on learning creates a solid platform for the development of the social aspect of ESD. Empathy, attitudes and values (i.e. *normative competence* (Wiek et al., 2011)) form an implicit foundation for this teacher education institution, which strongly acknowledges social sustainability, and aims to have a university culture that mirrors the culture of a sustainable school. The learning environment was therefore the focus from day one of the program.

Founded in sociocultural learning theory, the significance of a social community and the feeling of safety and well-being as an integrated part of the learning process were acknowledged. Further, a mentor arrangement was another initiative that was organised to develop a safe learning environment; the teacher educators acted as mentors for groups of student teachers and guided them throughout the study. This was coupled to a specific focus on peer guidance where the student teachers supervised each other on the written assignments and acted as each other's *writing buddies*. Peer guidance was also practised and emphasised in smaller assignments and group work and some student teachers had their practical training in pairs. In order to give extra support to student teachers from other countries who struggled with the language, these student teachers were designated specific writing buddies who also corrected linguistic errors.

When it comes to the sub-category *community engagement*, the key emphasis placed on ESD was important in itself in order to create engagement. Moreover, the emphasis on science in context linked the teaching to societal issues, which may also create an awareness and engagement in the community. Another aspect is related to phenomenon-based teaching and how it may create affection, as described earlier. Finally, in order to gain a more global perspective, the students were encouraged to undertake some of their practical training in a developing country.

As a part of *lived ESD*, *pupil participation* can be linked to the student democracy and the methods for teaching and learning where the pupils need to be engaged in their learning process (e.g. phenomenon-based teaching and inquiry learning). Dewey (1938) considered experiential learning as a democratic learning process, as the working methods required active learners who shared their experiences. This is also a part of self-regulated learning, which was enhanced through the emphasis on student logs.

Finally, when it comes to *sustainable school management/development,* the emphasis both on peer guidance and on the pedagogical development project have potential when it comes to school development. There was also a theoretical introduction to organisational development in the teacher education program, and action research and action learning were presented as suitable working methods for school development. The student teachers were also encouraged to use *action research* to monitor and develop their teaching, involving a dynamic process of planning, observing, evaluating and re-planning (Gjøtterud & Krogh, 2012).

How do the student teachers in the teacher education program demonstrate understandings of ESD?

An external evaluation of the teacher education programs (Dolin, Linløkken, Tonheim, & Bildeng, 2012) concluded that although ESD was evident in the teacher education programs, the student teachers did not perceive ESD to be holistically realised. Analyses of student evaluation schemes showed the same tendency, but they also showed that there were differences in the student teachers' views regarding the realisation of ESD in the teacher education program. Some student teachers tended to see the sustainability perspective in all teaching modules as well as in the general learning environment, while other student teachers claimed that ESD was not included in the teacher education program at all. In the following, we will present the results of the analyses of the individual student assignments with respect to how the student teachers demonstrated their understanding of ESD.

Figure 2 shows the percentage distribution of the sub-categories among the science education assignments. The diagram illustrates that most student teachers in the analysis were focused on science in context (81%). Several student teachers also discussed topics that were related to pupil participation (62%) and collaboration (38%).

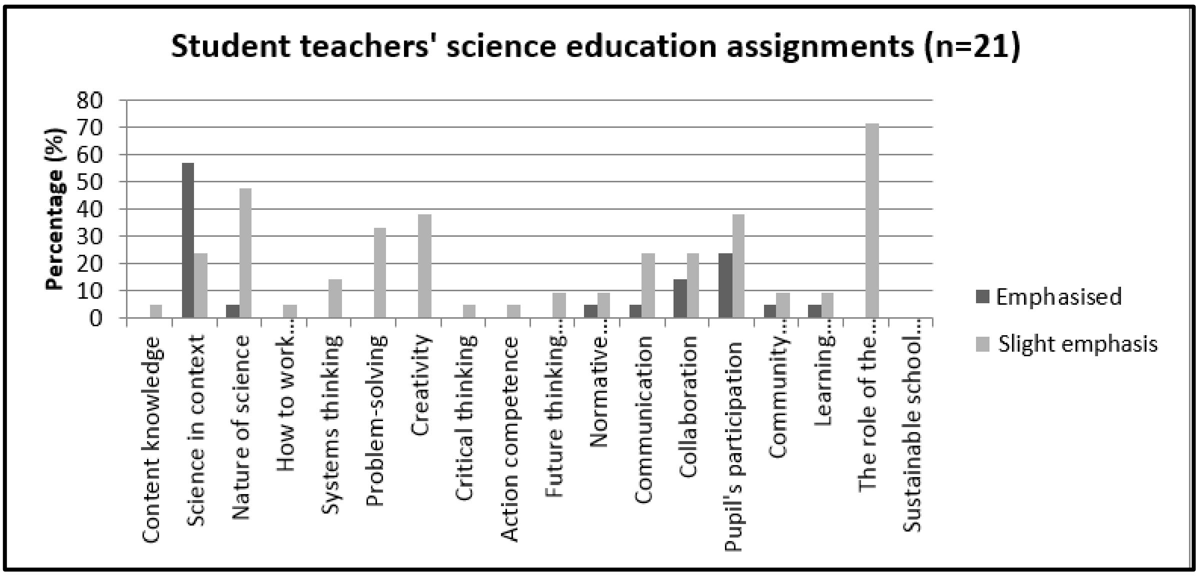

Figure 2. Percentage of science education assignments including sub-categories of ESD

Figure 3 shows the results of the analysis of the exam preparative assignments, where the student teachers reflected on how they had developed as teachers throughout the study. The student teachers focused on science in context (83%), pupil participation (50%) and collaboration (94%) in this assignment as well, but they also emphasised other sub-categories such as normative competence (45%), communication (56%), community engagement (56%)

and the learning environment (83%). All student teachers also wrote about the role of the teacher, but that was expected due to the task.

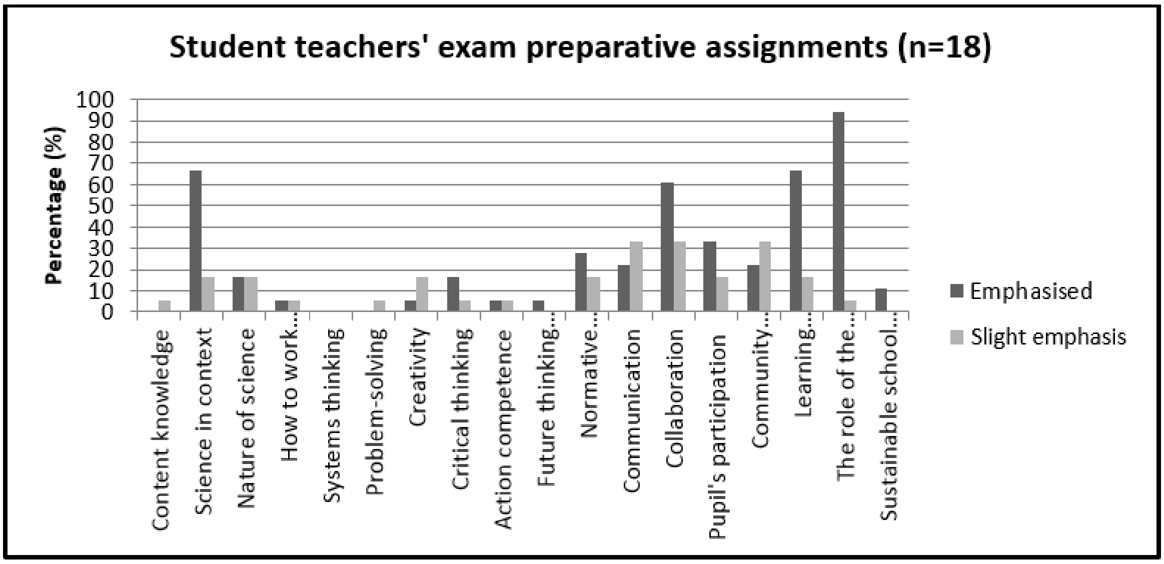

Figure 3. Percentage of exam preparative assignments including sub-categories of ESD

In the assignments, some student teachers demonstrated an explicit understanding of ESD, such as Erik, who had a background in ecology and nature conservation and followed the combined teacher education program in science and agriculture. He wrote about how he entered the teacher education program with a depth of knowledge about sustainable development, but that his experiences in the teacher education program changed his perception of ESD:

> My year in the teacher education program has taught me that ESD is much more than imparting knowledge about ecology. In retrospect, I would say that I have moved from looking at the school and my task as a teacher from teaching about sustainability, towards looking at my task as teaching for sustainability. I used to think about what the pupils needed to know about ecology and environmental management in order to understand sustainability, but I am now thinking more about how I can help the pupils to become independent, critical and creative problem solvers driven by their own engagement and empathy. (Exam preparative assignment, Erik)

Another student teacher who was explicit in terms of her perspective on ESD was Marianne who discussed the role of peer guidance in sustainable development of the school and school system:

> Peer guidance is an important tool because the teachers may develop a common understanding of how one should work in the school and why. It is required that teachers are open to suggestions, discussion and guidance from other colleges in order

> to encourage their own development and school development. I believe this is important in order to promote sustainable development of the school system. In this way, the school itself may become a learning organisation in which the pupils, teachers and management continuously evolve and learn. (Exam preparative assignment, Marianne)

Marianne also linked inquiry learning and ESD and was thereby explicit about the role of inquiry learning for ESD by pointing to how inquiry learning may facilitate creative and critical thinking and understanding for scientific working methods.

The excerpts taken from the assignments of Erik and Marianne were more particular than ordinary. Most other student teachers were less explicit with respect to their understanding of ESD. The focus on NOS and the ESD competencies of problem-solving, creativity and critical thinking in the assignments was mainly due to an emphasis on inquiry learning, as was drawn attention to by Marianne. In addition, when discussing science in context, several student teachers wrote about phenomenon-based teaching, such as in this excerpt by Mette, who showed an appreciation of phenomenon-based teaching as a tool with which to understand science in an everyday context:

> After being introduced to the topic of phenomenon-based teaching in this study, I have finally been able to identify something that was lacking from my studies: being able to connect the sciences to an everyday context. It was only at a later stage that I managed to move from abstract matter into the concrete, thus being able to see things from a broader perspective. (Science education assignment, Mette)

Discussion

The purpose of this study was to investigate how a teacher education institution with an overall aim of educating teachers who can contribute to sustainable development includes such practices in the education of science teachers. In this section, the findings from the case study will be used to discuss how ESD can be realised in science teacher education. We will begin with a focus on the student teachers and what they need to learn and experience in order to realise ESD. We will thereafter discuss the ESD realisation in the teacher education program under study and how the realisation can be improved.

Scott (1996) emphasised that teacher education programs should educate teachers who are both willing and able to contribute within ESD. In order to be able to realise ESD, a broad understanding of the concept is necessary (Hopkins & McKeown, 2002). We have earlier pointed to science teachers tending to be oriented towards the fact-based teaching tradition (Borg et al., 2012). In the excerpt from the student teacher Erik, he wrote that his understanding of ESD had changed throughout the study, moving from teaching *about* sustainability to teaching *for* sustainability. Hence, he moved from a fact-based to a pluralistic teaching tradition. The aim of the pluralistic tradition is to 'enhance the students' democratic action competence' (Rudsberg & Öhman, 2010, p. 97). It, hence, involves to become competent in acting consciously and participating reflectively in the sustainability debate (Öhman, 2007). This is in line with Erik's focus on helping learners become 'independent, critical and creative problem solvers driven by their own engagement and empathy'.

Scott (1996) also emphasised the need for a repertoire of suitable pedagogical approaches in order to be able to realise ESD. The model for planning and analysing ESD is one tool that can guide the realisation of ESD, and the model is designed in a way that allows the teachers to introduce ESD gradually (Jegstad & Sinnes, 2015). The teacher education program being studied founded the realisation of ESD in existing practices; the approach to ESD did therefore follow a strengths model (Hopkins & McKeown, 2002). From the analysis, we can see that the choice of working methods facilitated the development of specific categories of the model, in line with education through science (Holbrook, 2005). Thus, realising ESD is about finding teaching and working methods that facilitates for the development of ESD competencies and the other categories of the ESD model. We have already given specific examples in the result section, and some will be lifted up in this section as well.

Within lived ESD, the student teacher Marianne pointed to the role of peer guidance and how 'the school itself may become a learning organisation in which the pupils, teachers and management continuously evolve and learn'. She thereby pointed to how the teacher education program can facilitate sustainable school management and development. Further, through the university culture, the student teachers experienced a safe and friendly learning environment, where collaboration was important and where diversity, both among student teachers and teacher educators was valued (Sterling, 2009). Thus, through exemplary teaching experiences, such as peer guidance, the residential field course and the mentor arrangement, the student teachers experienced good relations and a good learning environment themselves, and the aim is that they will include similar practices in their future professions.

Phenomenon-based teaching and inquiry learning were other approaches taken towards ESD. According to the student teacher Mette, phenomenon-based teaching helped her 'move from abstract matter into the concrete, thus being able to see things from a broader perspective'.

This higher understanding and ability to see the broader picture is important within ESD, especially connected to the three perspectives of ESD, as ESD is often explained by a model emphasising the economic, social and environmental aspects (McKeown & Hopkins, 2003). Hence, when addressing scientific issues, they should be linked to the economic and social aspects as well. This requires seeing things from a broader perspective and is linked to the ESD competence systems thinking.

Within inquiry learning, the student teacher Marianne pointed to how inquiry learning facilitated pupil participation, introduction to scientific working methods and ESD competencies such as creativity and critical thinking. Since inquiry learning in this teacher education program was linked to complexity and SSIs, the importance of these competencies was increased.

The analyses showed that the focus in the student teachers' assignments was in accordance with the focus in the teacher education program, indicating that the teaching affected the science educational engagement of the student teachers. Especially the categories science in context, collaboration and pupil participation were emphasised. Societal relevance and pupil participation were key-issues throughout the year through the focus on phenomenon-based teaching, inquiry learning and other pupil active teaching methods and these were also topics many student teachers addressed in their assignments. Further, the student teachers had to collaborate in most sessions in the teacher education program – and many student teachers followed up with a focus on collaboration in their assignments.

Even though the foci of the assignments were in accordance with the ESD realisation in the teacher education program, there were some discrepancies in how the student teachers understood the ESD realisation. One explanation of this discrepancy is linked to how explicit the teacher educators were with respect to ESD in the teacher education program. To illustrate this by an example, Marianne's emphasis on sustainable school development and management was founded on her own interpretation. An important question is therefore linked to how we can ensure that the focus on ESD is made explicit to all student teachers. A characteristic found in the analysis of the teacher education program was that the ESD expression was somewhat implicitly covered and therefore not understood by all students.

In the teacher education program being studied, exemplary teaching is used. According to the local curriculum, the teaching should be experienced and discussed as a part of the program content (NMBU, 2009). Student teachers enter the teacher education program with preconceptions about teaching and learning; the inclusion of sufficient suitable experiences and opportunities for the student teachers to reflect on these experiences is therefore emphasised (Korthagen & Lagerwerf, 2001). This is in line with exemplary teaching, but it might appear as if parts of the meta-perspective were lacking from this teacher education program. It could therefore be suggested that more meta-reflection be included with respect to the ESD terminology and how ESD is realised. This is especially important in science education programs, since student teachers within a fact-based teaching tradition may need more explicit guidance in order to reveal the ESD expression and contribute with a teaching tradition more in line with ESD.

More meta reflection would also be necessary with respect to the realisation of the specific sub-categories. One suggestion could be to move the reflection on the ESD competencies forward in order to initiate an earlier awareness of the topic. This reflection could also include other elements of ESD and perhaps guide the student teachers in further development of their teacher competency throughout the program.

Another way to achieve the exemplary to be explicit enough, could be if the teaching staffs analysed their own teaching sessions in order to be conscious about the ESD aspect of their own teaching. The ESD expression has to be clear for the teacher educators in order to be clear for the student teachers. This would be especially important in a teacher education program where the strengths model has been applied in the development of the ESD expression, since the teacher educators build on something they have done earlier, before ESD was chosen as an overall aim. Such an analysis could also contribute to development of the ESD expression in the teacher education program, where the teaching staffs themselves are able to identify the potential and the strengths and weaknesses with their own teaching and thereby develop the realisation of ESD further.

Concluding remarks

In this paper, we have given an example of how a teacher education institution in Norway realised ESD through a strengths model by building on elements already present in the teacher education program, such as phenomenon-based teaching and inquiry learning. In case study research, a single case is preferred when the case represents a unique or rare case (Yin, 2009), such as in this study due to the overall aim of the teacher education program. Corcoran et al. (2004) stressed that every school or institution is different, and one should therefore not look for universal ESD models, but rather consider how the practice in one institution can be transformative for another institution. Consequently, they emphasised the importance of thorough documentation for the study to have transformative value for others. This is in line with reader-based analytical generalisation, introduced by Kvale and Brinkmann (2009), where the reader judges whether the findings may be generalised.

From the study, we can see that the emphasis on sociocultural learning theories contributed to social sustainability in terms of both the atmosphere of and the working methods employed in the teacher education program, and that the experiential learning and pupil-centred teaching approaches – such as phenomenon-based teaching and inquiry learning – built a thorough foundation for ESD competencies and other aspects of the ESD model. However, we also found that the ESD realisation needs to be explicit. Student teachers such as Marianne and Erik showed a well-developed understanding of ESD in their assignments, but many student teachers need more guidance and explicit teaching. They also need guidance about the concept of ESD. The expression of ESD was developed within the teacher education institution and is continuously in development through on-going research and development projects, and these are factors to be kept in mind.

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Science teacher education for sustainable development: A case study of a residential field course in a Norwegian pre-service teacher education program

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Abstract

In this paper, we explore how a Norwegian teacher education institution promotes education for sustainable development (ESD) through a residential field course. The residential field course was located in a mountain area and data was collected through participant observation. The data included – together with instructional artefacts – evaluation schemes and assignments written by the student teachers, and the analysis was based on categories for science ESD. Through exemplary teaching experiences in an outdoor environment and pupil-active teaching methods, such as inquiry learning and phenomenon-based teaching, the student teachers gained experience in outdoor education and of stepping into the unknown in a safe learning environment. This was further connected to ESD pedagogy.

Introduction

In this paper, we will present and explore a case from a Norwegian university. The teacher education program in this university has an overall aim of educating teachers who can contribute to sustainable development, and outdoor education is an important element of this aim. A residential field course is therefore arranged at the beginning of the teacher education program; from 2010–2012, all science and mathematics student teachers travelled to Finse, located in the north-western part of the Hardangervidda mountain plateau in Southern Norway for the residential field course.

The term *outdoor education* has different meanings according to geographical location. In the Scandinavian tradition it usually involves school-based learning outside the classroom (Fägerstam, 2014). Outdoor education can take place in several arenas not only limited to nature environments (Frøyland, 2010; Tal, 2012), but the focus in this article is on nature as an arena for teaching and learning.

Several studies have been undertaken in outdoor education, but the majority of these tend to focus exclusively on science knowledge and skills instead of on sustainability (Dillon, 2012). The research typically report about outcomes related to academic achievements and physical-, interpersonal- and affective impacts (Malone, 2008; Rickinson et al., 2004). Dillon et al. (2006, p. 107) claimed that '[f]ieldwork, properly conceived, adequately planned, well taught and effectively followed up, offers learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom.' Thus, the importance of outdoor education is clear, but its success is largely dependent upon the teacher and how the teacher facilitates the outdoor experience, also because the competency, behaviour and beliefs of the teacher affect his or her teaching (Burmeister, Schmidt-Jacob, & Eilks, 2013; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013).

The aim of the paper is to explore how a residential field course can contribute to education for sustainable development (ESD) in a pre-service science teacher education program. ESD includes developing respect for other human beings and for nature (UNESCO, 2006). However, a problem observed within ESD is the tendency for sustainability issues to become anthropocentric and for nature to be easily neglected when different interests are considered. Sandell and Öhman (2010) therefore stressed encounters with nature in order to widen the scope of environmental and sustainability education. Experiences with nature are reported to promote affinity towards nature and to introduce conservational behaviour (Malone, 2008; Palmer, 1998).

There is an increased global concern that the children of today spend less time outdoors, and Marcum-Dietrich, Marquez, Gill, and Medved (2011) warned that the current generation of teachers growing up indoors lack a basic understanding of the natural world from personal experience. In Norway, nature has played an important role in the lives of the people (Frøyland, 2010) and Norway is recognised internationally as a green country with strong outdoor traditions (Henderson & Vikander, 2007). However, the same trend with less nature experience among children is also observable here, mostly due to social factors related to time pressure (Skår, Wold, Gundersen, & O'Brien, 2016).

Research shows that pre-service teachers who have positive experiences of the outdoors tend to have intentions regarding future outdoor teaching (Blatt & Patrick, 2014; Vadala, Bixler, & James, 2007), yet both teachers and pre-service teachers report how there are barriers to taking pupils outdoors (Blatt & Patrick, 2014; Sinnes & Jegstad, 2011). Consequently, Blatt and Patrick (2014, p. 2261) emphasise

> a more robust role for teacher education programs in facilitating the interaction of pre-service teachers with the outdoors through projects, field trips, field studies, etc. in order to (1) build on their prior outdoor experiences and (2) provide them with instructional techniques for exposing their students to nature and the outdoors.

Thus, including outdoor education in teacher education programs is essential for the realisation of ESD. However, nature in itself cannot make a substantial impact if the appropriate pedagogy is not considered (Tal, 2012), and through the investigation of this field course, we therefore aim to exemplify how different pedagogies related to outdoor education facilitate the realisation of ESD. The research question addressed in the paper is: *How does an ESD-oriented science teacher education program realise different approaches to ESD through a residential field course?* The focus in this paper is on what was taught, but the perspectives of the student teachers are also included to give a richer picture of the residential field course.

The ESD elements of the residential field course were analysed using the categories from an ESD model for planning and analysing science ESD (Jegstad & Sinnes, 2015). The categories were content knowledge, science in context, the distinctiveness and methodological character of science, ESD competencies and lived ESD, and will be listed together with their sub-categories in Table 1 in the methodology section.

The model was developed with a focus on *education through science* (Holbrook, 2005) – where the emphasis is on how general educational skills may be promoted *through* the subject of science. Thus, there are both science-specific and more general categories, and the mentality behind the model is that ESD can be realised, even when sustainability is not specifically taught as content, simply through the other categories of the model (Jegstad & Sinnes, 2015).

Methodology

The paper is written as a part of a larger case-study project where the realisation of ESD in a teacher education program for candidates with an academic educational background in science was investigated (Jegstad, Sinnes, & Gjøtterud, in press). The teacher education program amounted to 60 ECTS credits (one-year full-time study) and was organised through twelve, week-long modules. In this paper, one of the first modules is studied.

A case study 'investigates a contemporary phenomenon in depth and within its real life context', and is applicable when explanatory questions, such as 'how' and 'why' questions are posed (Yin, 2009, p. 18). It is considered an appropriate research tool for studying sustainability in higher education due to its flexible nature (Corcoran, Walker, & Wals, 2004). In case study research, a single case is preferred when the case represents a unique or rare case (Yin, 2009), such as in this study due to the overall ESD-aim of the teacher education program.

The context of the residential field course

In 2012, 43 student teachers and 8 lecturers took part in the 3-day residential field course at Finse. The field course was built upon the same pedagogical principles as the overall teacher education program, that is, with an emphasis on sociocultural learning theory, experiential learning theory and self-regulated learning (Gjøtterud, 2011). Founded in experiential learning, the use of teaching approaches where the learners are especially active, such as *phenomenon-based teaching* were included in the residential field course. Phenomenon-based teaching is an inductive teaching approach, where theory is introduced to the learners after they have been exposed to a phenomenon representing the theory (Dahlin, Östergaard, & Hugo, 2009). *Inquiry learning* is another active learning process applied in the teacher education program and relates to methods that support the pupils in learning about scientific inquiry and in developing knowledge of science concepts and nature of science through an inquiry process (Crawford, 2014). In this teacher education program, inquiry learning is to a large extent linked to complexity and socio-scientific issues.

The field course had three focus areas: (1) the student teachers' ability to spot or create subject issues in an outdoor context; (2) preparation for their practical training, i.e. how to prepare teaching and how to encounter and guide the pupils; and (3) creating a social and safe learning environment by building social relations both among the student teachers and with the lecturing staff. These three aspects were closely connected and intertwined in the program for the field course.

The following nine teaching sessions constituted the residential field course:

- *Lecture about Finse as an arena for learning science*: A retired biology teacher held a lecture about Finse as an arena for learning science. She has brought pupils to Finse for more than 20 years, and her lecture covered topics on geology, plant and animal adaptations to the mountain climate, and changes in density and distribution among some animals, e.g. lemmings and the artic fox.
- *Aesthetics at Finse:* The student teachers created artistic expressions of their individual strengths as teachers. The installations were based on their encounters with the surroundings and elements found in nature.
- *Botanical fieldwork*: The student teachers explored different fieldwork techniques in biology and different ways of analysing the botany in the mountain area.
- *The mathematics and physics in the Railway Navvy Museum:* The student teachers created teaching plans based on the equipment in the Railway Navvy Museum located at Finse.
- *The chemistry and biology of Finsevannet:* The student teachers participated in a short version of a roleplay, where they were researchers analysing the local lake in an inquiry project.
- *The starry sky as an arena of teaching:* A lecture was held about the starry sky as an arena of teaching and the student teachers used rotating star maps to locate the stars in the sky.
- *Teaching preparation, practice and guidance:* The student teachers prepared and performed a short teaching session. The student teachers worked in groups and chose

what topic they wanted to teach, but they had to use the surroundings as a foundation for their teaching session. In addition to planning and performing their own teaching, the student teachers gave feedback and guided other groups in their teaching.

- *Learning outdoors – what, why and how?* A lecture was held with some group work included. The topics in focus were why we should bring pupils outdoors; different types of outdoor education; laws and regulations for outdoor education; the challenges of bringing pupils outdoors; important elements in good outdoor education; important factors for the outcomes of outdoor education; and suggestions for useful webpages within outdoor education.
- *The campfire and other social aspects:* The social aspects were emphasised throughout the field course and was one of the reasons why a cabin in the mountains was chosen as the location for the residential field course. On the last night, there was a camp fire where socialisation was in focus. A group of student teachers was in charge of the campfire, and they were responsible for preparing both the practical aspects of the event and social happenings such as songs, quizzes and other activities around the fire.

Data collection

The research was carried out in our own organisation and the field course was followed over three consecutive years (2010, 2011, 2012). The paper builds mainly on data from the field course in 2012. Both the second- and third authors have been responsible for the development of the field course, but they did not attend the field course the year under study. The first-author was co-hosting the session *the chemistry and biology of Finsevannet.*

Data was collected through direct observation and participant observation by the first author. The session *the chemistry and biology of Finsevannet* was observed through participant observation due to the role of the first author in this session. All other sessions except *botanical fieldwork* and *the mathematics and physics in the Railway Navvy Museum* were observed through direct observation in 2012. *Botanical fieldwork* was observed through direct observation in 2011. The sessions *teaching preparation, practice and guidance* and *the campfire and other social aspects* were observed through participant observation in 2011, in addition to the direct observation in 2012. The first author also carried out participant observations in meetings which involved planning for the teaching sessions.

The data corpus also included handouts and presentations, and evaluation schemes and assignments from the student teachers. Even though 2012 was the main year of study, data from the other years was included as well, both as contextualising data in order to achieve a wider understanding of the residential field course and as a supplement to the core data. The data analysed is listed in Table 1 below.

Table 1. List of data material used to analyse the residential field course.

Data	**Status of data**	
	Core	***Contextualising***
A letter handed out to the student teachers before the module	X	X
Field notes from direct observation	X	X
Field notes from participant observation	X	X
3 handouts given to the student teachers in the teaching sessions and the session on the chemistry and biology of Finsevannet	X	
2 PowerPoints from the sessions about the starry sky and learning outdoors	X	
Transcription from meetings planning the field course		X
Summary of the evaluation schemes from the field course	X	
10 exam-preparative assignments written before the oral exam in 2012	X	

The last day of the field course, there was a written evaluation, where the student teachers reflected on how they had benefitted from the field course and how they had been working with different aspects of ESD. A summary of these evaluation schemes was included in the data material.

The exam-preparative assignments written by the student teachers graduating in 2012 were also included. In these assignments, the student teachers reflected on how they had developed as teachers throughout the study. The assignments play a major role in the teacher education program as a tool helping the student teachers to reflect on and become aware of the teacher competency they have developed (Gjøtterud, 2011). Two thousand twelve was the only year the assignment was given in science education and pedagogy combined (as opposed to only pedagogy in the other years) and the assignments were therefore richer compared to the other years. Neither ESD nor outdoor education were given topics in the assignment, but some student teachers still reflected on the field course. Seventy-five student teachers completed the assignments, and ten of them wrote about their experience at Finse. The student teachers wrote about either specific sessions or how the field course as an entity had contributed to their development as teachers.

In order to isolate the relevant assignments written by the student teachers, we used the search word 'Finse' in a folder search. The student teachers writing the assignments had attended the field course in 2010 or 2011, but the assignments were still included in the analysis, since the student teachers pointed to aspects of the field course that were not related to the specific year.

Data analysis

The residential field course was analysed using *meaning categorisation* (Kvale, 1996). The categories used were the 18 sub-categories of the ESD model (Jegstad & Sinnes, 2015) listed in Table 2 below. The categories of the ESD model were developed with secondary schools in mind and four out of five main categories therefore focus on the pupils and what the pupils need to know or be able to do. The sub-categories in lived ESD were, on the other hand, divided between pupils (community engagement), the teacher (pupil participation, the learning environment and the role of the teacher) and the school as an organisation (sustainable school management/development). All categories have a distinct meaning within the secondary school context and imply what the pupils are to learn; the teachers need to teach accordingly, and the categories are therefore useful for teacher education as well. Thus, even though the sub-categories were developed in advance, their meanings were expanded in the context based on the ESD construction in the teacher education program (Jegstad et al., in press).

Table 2. Categories used in the analysis of the empirical material.

Main category	Sub-category
Content knowledge	Content knowledge
Science in context	Science in context
Science's distinctiveness and methodological character	Nature of science
	How to work sustainably in science
ESD competences	Systems thinking
	Problem-solving
	Creativity
	Critical thinking
	Action competence
	Future thinking and belief
	Normative competence
	Communication
	Collaboration
Lived ESD	Pupil participation
	Community engagement
	Learning environment
	The role of the teacher
	Sustainable school management/development

Each session was coded with respect to the inclusion of the categories. The analysis was carried out on two levels: (1) whether the category was present and (2) to what extent it was present. For this second dimension, we differentiated between *slight emphasis* (the category was focused on implicitly through collateral learning, which is what one learns through and by doing other things) and *emphasised* (the category was explicitly focused on).

We will exemplify the analysis using the aesthetics at Finse session. In this session, the student teachers created artistic expressions with elements found in nature. Each installation was supposed to express the student teacher's individual strengths as a teacher and was presented to their fellow student teachers at the end of the session. The task itself demanded *problem-solving* and *creativity* and they were supposed to think about their *role as a teacher*. Thus, these three categories were emphasised. Further, they used elements from the context and they had to imagine themselves as future teachers, which also put *science in context* and *future thinking and belief* on the list of emphasised categories. *Communication*, *normative competence* and *friendly and safe learning environment* were categories that were implicitly covered in the presentations and therefore had slight emphasis; the student teachers had to be good listeners when they presented to each other. Finally, the task implied student-active methods and *pupil participation* was therefore also implicitly covered through collateral learning. Similar analyses were undertaken of the other sessions and an overview of the results of the analysis of the field course is given in Table 3 in the findings and through descriptions.

The sub-categories of the ESD model were also the foundation for the analyses of the student evaluation schemes and the exam-preparative assignments. Translated excerpts from both kinds of data are included in the descriptions of the sessions in order to get an increased understanding and richer results. The excerpts from the assignments were chosen because the student teachers, in different ways, explicitly described how the residential field course contributed to their development as teachers. The names used in these excerpts are pseudonyms. The excerpts from the evaluation schemes were chosen either because of explicit descriptions – or because they were typical.

The project and the involvement of the student teachers and their assignments was approved by a consultant on research ethics in Norwegian Social Science Data Service. The teacher educators responsible for examination were not involved in data collection and analysis.

Findings

Table 3 illustrates the realisation of ESD in the residential field course. We then present and explore four sessions in depth: aesthetics at Finse; the chemistry and biology of Finsevannet; teaching preparation, practice and guidance; and the camp fire and other social aspects of the residential field course. These four sessions were chosen because of the variety in the way in which ESD was realised.

Table 3. Summary of the analysis of the teaching sessions with respect to the sub-categories of the ESD model.

ESD categories	Sub-categories	Teaching sessions								
		Lecture about Finse as an arena for learning science	*Aesthetics at Finse*	*Botanical fieldwork*	*The mathematics and physics in the Railway Navvy Museum*	*The chemistry and biology of Finsevannet*	*The starry sky as an arena of teaching*	*Teaching preparation, practice and guidance**	*Learning outdoors – what, why and how?*	*The camp fire and other social aspects*
Scientific content knowledge	Knowledge of concepts and systems relevant for sustainability	E		S		S		S/E		
Science in context	Science in the society, nature and sustainability issues	E	E	E	E	E	E	E	E	
Science's distinctiveness and meth. Character	How to work sustainably in science					E			S	
	Nature of science	S		E	S	E	E		S	
ESD competencies	Systems thinking	S			S	S		S/E		
	Problem-solving		E	E	E	E		E		
	Creativity		E		E	S		E		
	Critical thinking				S	S		S/E		
	Action competence				S			S		
	Future thinking and belief		E							
	Normative competence		S					E		S
	Communication		S					E		S
	Collaboration			S		S		E	S	S
Lived ESD	Pupil participation		S	S	S	S	S	S/E		E
	Community engagement	S				S		S		
	Friendly & safe learning environment		S					E		E
	The role of the teacher	S	E	S	E	S	S	E	E	S
	Sustainable school management/development									S

The results from the analysis show whether ESD had slight emphasis (S) through collateral learning or was emphasised (E). (*) The teaching sessions are marked with S/E in some cells. The student teachers worked in different groups and placed a different emphasis on the categories.

Aesthetics at Finse

In the aesthetics at Finse session, the student teachers had to use their creativity in making artistic expressions of their individual strengths.

The following assignment was given to the student teachers:

> (1) Spend 1 minute to think about your strengths as a teacher. (2) Find 3-6 things in the surroundings that may represent you as a teacher, be open and flexible in your observation so that the surroundings may talk back to you and influence how you look at yourself as a teacher. (3) Find a place that symbolises you as a teacher. (4) Create an installation in this place. (5) Come up with a title for your installation. (Hand-out to the student teachers)

The session started by a short introduction by the two teacher educators hosting the session. They prepared the student teachers for the task, and one of the teacher educators also drew the line between the task and sustainable development:

> When it comes to sustainable development, which is a topic in our teacher education program, this is highly relevant with respect to moralising: one needs to give up on some things to improve the well-being of nature. By achieving an emotional connection to nature, this renunciation will feel smaller because of an increased pleasure for nature. (Field notes, first author)

Observation indicated that many of the student teachers found the assignment to be quite challenging. With a background in mathematics and science, the task probably required a new way of thinking, and creativity was one aspect of the task. Another aspect was the personal part of the task, where they had to expose themselves to the other student teachers and step into the unknown. The unknown in this respect was linked to both the new way of thinking and exposure of their thoughts, but stepping into the unknown could also be about testing out new teaching methods or other aspects relevant for the teaching profession, which we will return to in the discussion.

The student teachers also had to use the environment. A teacher educator introduced teaching in the mountain area founded in an art exhibition called ‘Imagine being here now’, focusing on how distractions in today’s world can take you away from where you are and the different ways of being in a place. The student teachers were therefore challenged to be in the place as science teachers and spot subject issues in the surroundings. Finally, the teaching session contributed to lived ESD, since the student teachers reflected on their role as future teachers.

By reflecting on both their strengths and weaknesses as teachers, the student teachers may become aware of which aspects to accentuate and which to develop further.

The chemistry and biology of Finsevannet

In this session, the student teachers were introduced to a real-life case. The problem formulation given was:

> In the time period 1933 to 1973, there were big changes in Finsevann. (…) 40 new years have passed. Have the nutrients in Finsevann changed, and in that case – what might be the consequences for the foundation of growth for the brown trout in the water? (Hand-out to the student teachers)

Each group examined and evaluated two parameters linked to the case. At the end of the session, there was a brief educational reflection with emphasis on preliminary work and supplementary work in the classroom, and the role of inquiry learning. There was also a discussion about how chemists can take their samples in the field and follow up with analyses in the laboratory.

The student teachers were divided into groups based on their educational background from a line-up. They lined up from chemists to the right to limnologists (i.e. fresh water ecologists) to the left. The following was written in the evaluative section of the field notes:

> This was a nice introduction to inquiry learning, which is a topic covered more thoroughly later in the teacher education program. Using a real-world case seemed to engage the student teachers. The benefit of heterogenous groups was that the student teachers could contribute with their fields of expertise. (Field notes, first author)

Looking at the results in Table 3, all main categories of the model were realised in this session. Content knowledge was realised through the chemical and biological parameters examined. Introducing a case, such as in this session, was linked to the science in context category and makes the teaching session relevant for the attending learners. Through inquiry learning and educational reflections, the student teachers were introduced to the nature of science and scientific working methods, which are founding elements of science's distinctiveness and methodological character. How to work sustainably in the field was also discussed. Further, the ESD competencies problem-solving and creativity were present in approaching the task, systems thinking and critical thinking in interpreting the findings, and collaboration throughout all steps of the process. Finally, the case itself may lead to community engagement. There was also a discussion about preliminary and supplementary work in the classroom linked to the role of the teacher.

Teaching preparation, practice and guidance

A major part of the residential field course was devoted to teaching sessions, where the student teachers gained experience in teaching outdoors. They had to plan a 15-minute teaching session using the surroundings as the point of departure. This teaching session was conducted for three other groups of student teachers, who both acted as pupils and assessed the teaching session.

The teaching session was especially important within the science in context category, since it may be easier to include outdoor arenas later on in their teaching if they already have experience in outdoor education. Planning the teaching required problem-solving, creativity, communication, collaboration and a friendly and safe learning environment within the groups and they had to pay close attention to the role of the teacher throughout the planning. Creativity was especially in force due to the mountain surroundings with limited teaching resources. Some groups also covered topics directly related to sustainability issues.

In the evaluation schemes from the field course, several student teachers pointed to how this part of the field course had been beneficial. Specifically, they put forward planning creative teaching sessions and one student teacher articulated:

> We have used our minds in a different way and made teaching sessions which use 'nature as it is'. (Evaluation scheme, quote 1)

For some student teachers, this was their first encounter with teaching, an aspect which made the session especially demanding. The student teacher Solveig wrote the following in her assignment about the teaching experiences:

> At Finse, we were thrown into assignments where we had to learn about and use the teaching conditions. It was a brutal week, where I really felt my own insecurities. The week still felt nice, because I understood the relations between the planning and the conditions for teaching. (Exam-preparative assignment, Solveig)

When the groups of student teachers taught each other, the student teachers also gained experience in guiding their fellow student teachers by giving descriptive feedback and asking open and explorative questions. The student teachers were supposed to learn to be specific in their feedback and to give reasons for their interpretations. Descriptive feedback may mirror the student teachers and give them opportunities to assess the qualities of the teaching session by themselves. Hence, they learn how to reflect and initiate reflection on their own teaching, thus developing an inquiry-based mind. In this part of the session, normative competence was especially in force; many of the student teachers were unsure about the teaching situation and they had to show empathy towards each other both in the teaching sessions and when guiding each other. The student teachers taught in groups for smaller groups in order to feel safe in the teaching situation.

In the evaluation schemes, the student teachers showed appreciation of what they had learned from each other, both within and between the groups:

> I have gotten a lot of ideas by observing the other groups in their teaching activities. (Evaluation scheme, quote 2)

> The teaching sessions were creative and educational, and showed that most topics can be included in outdoor education. (Evaluation scheme, quote 3)

The student teacher Eva followed up on the latter statement in her assignment:

> I was particularly inspired by the session where we used a small area at Finse; we were supposed to describe the development of the ecosystem, just by looking at the pebbles. (Exam-preparative assignment, Eva)

Several other student teachers wrote about how they were inspired by the sessions on the field course and had or intended to use similar sessions in their own teaching. Hege wrote about how her teaching session had inspired her and given her ideas for future teaching in mathematics:

> At Finse, I was in a group developing an outdoor teaching session in mathematics. We made a teaching session connected to linear functions and modelling and used lichen as a phenomenon. This teaching session was very good, and I will use similar sessions in my teaching, especially in the more practical math courses. The concept of linking theory to practical mathematics shows the pupils the purpose of the subject. Feeling the wind in your hair, while doing mathematics, is not very common, and it is another reason to expand the use of it. This is also related to the confluent pedagogy where the emphasis is on the body as a part of the learning experience. (Exam-preparative assignment, Hege)

Hege emphasised the importance of contextualising teaching and related it to both phenomenon-based teaching and confluent education. Confluent education is founded in experiential learning theory and is a holistic pedagogy where the intellectual, emotional and psychometric perspectives are merged (Grenstad, 1986) and we will return to how it is related to ESD in the discussion.

The camp fire and other social aspects of the residential field course

From Table 3, we can see that the ESD competencies normative competence, communication and collaboration, and several of the sub-categories within lived ESD were evident in the social aspects of the residential field course. Social relations, both among the student teachers and between the student teachers and the lecturing staff, are important in order to create a friendly and safe learning environment and acknowledged as an important aspect of the ESD aim in the teacher education program. The field course is regarded as a unique arena for this purpose. The social process had already started when the group left the university and travelled to Oslo by bus, and it continued throughout the four-hour train ride. At Finse, both lecturers and student teachers stayed in the same cabin, ate all of their meals together and shared rooms with two to five others. Further, most educational activities were carried out in groups. A friendly and safe learning environment is considered an important foundation for the student teachers' development as teachers.

The student teachers were in the evaluation schemes asked how they had been working with the learning environment and/or social sustainability during the field course and the student teachers had different perspectives. Several student teachers pointed to the learning environment:

> Very good! We have been practising collaboration, observation, giving and receiving feedback. We also worked with the importance of including all pupils, how to divide the pupils into groups and create a safe learning environment. (Evaluation scheme, quote 4)

> I have been talking to many people and have worked in 'new' groups. I have gained confidence, which improves the learning environment. (Evaluation scheme, quote 5)

Other student teachers, however, did not reveal the emphasis on the learning environment:

> Social sustainability is not a notion I am acquainted with. The learning environment has been a natural part, but it has not been emphasised. (Evaluation scheme, quote 6)

> I don't feel that we have been working with this perspective, except that we have been together all day long, of course. (Evaluation scheme, quote 7)

We will return to the diversity of these answers in the discussion.

In the previous excerpt from the student teacher Solveig, she pointed to a brutal week, and in the evaluation, some student teachers also pointed to 'being out of one's comfort zone' and how 'the field course was overwhelming, but good'. For some student teachers, the field course at Finse was even more brutal and a new experience in many ways, such as for Miranda who has an immigrant background:

> At Finse, several approaches to teaching and learning were central: place-based teaching and learning, inquiry learning, experiential learning and phenomenon-based teaching. At this time, I did not really understand what science education was about (as opposed to pedagogy), but my experience at Finse was the best. We were challenged in creating a teaching session based on the surroundings. This was exciting and, for me, a way to get to know the other student teachers. It was like a big family on a working holiday. I also got an opportunity to be close to Norwegian nature. (Exam-preparative assignment, Miranda)

For Miranda, it was not only her first encounter with teaching, but also the first close encounter with the Norwegian mountain area and perhaps also the Norwegian culture.

Discussion

The research question posed in this paper was: *How does an ESD-oriented science teacher education program realise different approaches to ESD through a residential field course*? In the discussion, we will address this research question by first pointing to the role of outdoor education in ESD. We will thereafter discuss how the choice of pedagogies and teaching approaches facilitated the ESD realisation.

In the student evaluation, one of the student teachers wrote, 'we have been outdoors in a landscape that evokes a genuine inner desire to contribute to sustainable development, both personally and in the role as a teacher.' This is in line with the literature (Malone, 2008; Palmer, 1998) that confirms the role of outdoor education in ESD. However, a linear relationship between nature experience, love for nature and becoming environmentally concerned has been much discussed. Outdoor education, and nature encounters specifically, is regarded as important for public environmental concern, but Sandell and Öhman (2013) warned against 'an oversimplified belief in a general causal relationship between rich experiences of nature, environmentally-friendly attitudes and behavioural change' (pp.36-37). Their objections were founded in the unclear meaning of 'being environmentally concerned' and the two possible motives for outdoor experience: instrumental and intrinsic. Following an instrumental motive, outdoor education is employed as a means for different purposes (e.g. physical and mental health, group solidarity, developing ecological knowledge etc.) and other educational paths and arenas can also be used. Regarding the intrinsic motive, the experience is an aim in itself to achieve 'an affiliation with nature and a sense of humility towards the various non-human forces that can be experienced outdoors' (Sandell & Öhman, 2013, p. 43). Thus, the experience cannot be achieved in another environment.

During the residential field course, aesthetics at Finse was the only session with a purely intrinsic value. However, the instrumental value in outdoor education can also give rise to an intrinsic experience as long as the intrinsic value is given space (Sandell & Öhman, 2013), which was the case in other parts of the field course. The field course in itself has intrinsic value, as the student teachers were brought outdoors in order to be close to nature and experience outdoor education. A more specific example is the teaching sessions where the student teachers develop authentic contextualised teaching sessions.

The intrinsic value of outdoor education can in turn be linked to motivation, which is a crucial element in ESD, since the learners need to be motivated in order for ESD to be successful (Darner, 2012; Murray, Goodhew, & Murray, 2014). Being motivated means '*to be moved* to do something' (Ryan & Deci, 2000, p. 54, originial emphasis). Ryan and Deci (2000) emphasised *intrinsic* motivation (as opposed to extrinsic motivation), which is when the task itself is interesting and the person gains inherent satisfaction by acting on it. An aim within ESD would be to facilitate for – or catalyse – intrinsic motivation. However, intrinsic motivation can only occur if the activity holds an intrinsic interest for the individual (Ryan & Deci, 2000), which accentuates the need for affection and affiliation with nature and the importance of outdoor education.

With increased immigration and diversity in the Norwegian population, the importance of outdoor education in the teacher education programs is even more crucial. We concluded the findings section with an excerpt from Miranda, who had her first close encounter with the Norwegian wildlife and traditions at Finse. Miranda pointed to the opportunity she got in being close to Norwegian nature, but also her experience of being at a cabin when she stated: 'It was like a big family on a working holiday.' Even though nature has played (and still plays) an important role in the lives of Norwegian people, citizens from other parts of the world may not be familiar with the Norwegian use of the nature, and a residential field course like this can therefore be a good introduction to the Norwegian culture and traditions such as 'cabin life'.

We have earlier referred to Tal (2012), who emphasised the importance of pedagogy for outdoor education to make a substantial impact. Dewey's (1938) ideas about education have been used to advocate outdoor education and other forms of student-active learning (Wong &

Pugh, 2001). Dewey (1944, p. 74) defined education as 'that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases the ability to direct the course of subsequent experience'. His emphasis was not on experience in general, but having *an* experience:

> Experience occurs continuously, because the interaction of live creature and environing conditions is involved in the very process of living. (…) Often times, however, the experience had is inchoate. Things are experienced, but not in such a way that they are composed into an experience. (…) [W]e have *an* experience when the material experienced runs its course to fulfilment. (Dewey, 1934, p. 35)

Thus, according to Dewey, educative experiences do not emerge from student activity (e.g. projects, group-work) or a particular environment (e.g. labs, field trips), but in transformative experiences that are valuable in themselves and that can lead to other valuable experiences (Wong & Pugh, 2001).

Founded in these ideas, the teacher education program under study includes teaching approaches where the learners are especially active and reflection on these experiences. Inquiry learning is such an approach, which also provides opportunities for the further promotion of outdoor education (Dillon, 2012) and ESD (Burmeister, Rauch, & Eilks, 2012). The potential for ESD in inquiry learning can be seen from the analysis of the session the chemistry and biology of Finsevannet, indicating that inquiry learning has the potential of realising all categories of the ESD model. This potential has also been revealed in prior work (Jegstad et al., in press), where it was found that inquiry learning in particular contributed within the development of specific ESD competencies: *problem-solving* and *creativity* in answering the issue raised; *systems thinking* and *critical thinking* in order to assess the results; and *collaboration* and *communication* since the task often is given to groups of learners.

Phenomenon-based teaching is another learner-active teaching approach, which was addressed through aesthetics at Finse and the teaching sessions where the student teachers created learning activities from nature. The emphasis on phenomenon-based teaching attempts to supplement and expand the constructivist and fact-based approach to science education often found among teachers and student teachers in science education (Gjøtterud, 2011), and is therefore a way to contribute to a teaching tradition in line with ESD.

The way teachers teach is embedded in years of formal and informal teaching and in their preconceptions about teaching and learning formed through these experiences (Evans, 2015;

Korthagen & Kessels, 1999). Borg, Gericke, Höglund and Bergman (2012) investigated subject-bound differences among teachers in realising ESD and found that science teachers tended to be oriented towards the fact-based teaching tradition, where environmental issues are seen as knowledge problems which can be solved by carrying out more research and informing the public (Rudsberg & Öhman, 2010). The pluralistic tradition, on the other hand, is more in line with ESD principles and acknowledges different perspectives, views and values; the aim is for the pupils to develop knowledge and skills so that they can actively and critically evaluate sustainability issues (Öhman, 2007). Korthagen and Lagerwerf (2001, p. 201) warned that 'if [the student teachers] enter the program with a view of teaching as the transmission of knowledge, then theories building on other views will be only partly incorporated into these gestalts, and thus into their behaviour in the classroom'. They therefore suggested the inclusion of sufficient suitable experiences and opportunities for the student teachers to reflect on these experiences. Making the student teachers aware of their legacy and reflect on their teaching experiences with this legacy in mind is therefore an important element of the development of their teacher competence (Gjøtterud, 2011), and in turn ability to realise ESD.

The ability to connect the sciences to an everyday context is another important contribution of phenomenon-based teaching. Throughout the residential field course, the student teachers were challenged to spot subject issues in the surroundings, and the student teachers showed appreciation of using 'nature as it is' and 'describ[ing] the development of the ecosystem, just by looking at the pebbles'.

Phenomenon-based teaching also provides the student teachers with possibilities to be affected by the environment (Jegstad et al., in press). When the teacher educator introducing aesthetics at Finse stated 'by achieving an emotional connection to the nature, this renunciation [i.e. give up on material things] will feel smaller because of an increased pleasure', he is in accordance with literature stating that a direct personal encounter with nature can work as inspiration for sustainable development since the intrinsic value of the experiences 'often indicate values that contrast with the conventional view of development in terms of material consumption' (Sandell & Öhman, 2013, p. 49). This can be considered extra beneficial in the session aesthetics at Finse, since learners may open their senses and bond with nature when creativity is nurtured in artistically oriented EE (Daskolia, Dimos, & Kampylis, 2012).

In the result section, we also pointed to how the student teachers had to step into the unknown, such as in aesthetics at Finse and in outdoor education in general. The ability and confidence to step into the unknown is an important part of ESD. Student teachers have to step into the unknown and create a new mind set when they are going to move away from the fact-based teaching tradition, which has dominated their higher education, and towards a pluralistic teaching tradition. Hence, ESD in science education requires teachers who are willing to explore content knowledge without fixed answers, since sustainable development is considered to be a socio-scientific issue (Simonneaux & Simonneaux, 2012) in terms of climate change etc. Further, ESD also requires the inclusion of teaching methods focused on more than imparting content knowledge, such as developing ESD competencies and other aspects related to the categories of the ESD model. The student teachers therefore need to have a conscious focus on the choice of teaching and learning methods and create teaching sessions that will contribute to the development of, for example, specific competencies (Jegstad & Sinnes, 2015). The combination of uncertain knowledge and creative teaching methods was perceived challenging for some of the student teachers. For these, it might be that stepping into the unknown can be extra beneficial. Thus, the student teachers writing about ‘a brutal week’ and ‘being out of one’s comfort zone’ may have gotten important experiences. Spotting subject issues and being inspired by each other, as well as learning creative teaching methods that engage and motivate, are other important experiences.

Even though some student teachers found the residential field course, and particularly the teaching sessions, to be brutal, the teacher educators attempted to make the experience as safe as possible. Several student teachers had their first teaching experience at Finse, and they were unsure about the situation. The teaching was therefore carried out in groups with a small number of student teachers as pupils, in order for the student teachers to feel safe. In order to make the experience feel even safer, the student teachers participating as pupils could have been fewer, but this would also have reduced the number of groups and, consequently, the number of examples of outdoor education. Further, for some of the student teachers, the teaching experience was overwhelming in itself, regardless of the number of participants.

The residential field course is deeply founded in the learning theories which the teacher education program builds upon, and we have already pointed to the role of experiential learning. Sociocultural learning theory (Lave & Wenger, 1991; Vygotsky, 1978) also contributed with an emphasis on the social community and collaboration as a part of the teaching, learning and knowledge building, and the emphasis on the learning environment originated in this theory. The field course was also related to confluent education, where the aim is to facilitate the individual learner to achieve optimal development and growth in order for him/her to take care of him- or herself and others in a wider context (Grenstad, 1986). In other words, confluent education is in line with ESD-principles, through an emphasis on the whole person, and appreciating and nurturing the potential of each individual (Sterling, 2009; Wals, 2011).

Confluent education was also present in the residential field course through *exemplary teaching* – or *the realistic approach* introduced by Korthagen (2001) and related to the suitable experiences addressed earlier. The realistic approach builds on concrete experiences and the concerns and gestalts these evoke, and bridges the gap between educational theory and actual practice. The residential field course is pervaded with exemplary teaching. The student teachers experience most sessions as pupils, for example when they are participating in the roleplay about Finsevannet and when they are receiving guidance from each other in the teaching sessions. The teaching is experienced and discussed as a part of the program and the student teachers can use the same approaches in their future profession in order to allow their pupils to reflect on their learning.

The field course is also in itself a part of exemplary teaching. In Norway, residential field courses are quite common in order to create positive learning environments in schools. However, it is not common to include such field courses in teacher education programs. Here, establishing positive relationships is part of social sustainability in the teacher education program and the emphasis is on sociocultural learning theories. However, even though exemplary teaching has potential, there is a risk that the teaching is too implicit for the student teachers to realise its full potential, which can be seen in the discrepancies in the student teachers' responses with respect to social sustainability. Thus, meta reflection is important.

Concluding remarks

In this paper, we have explored how a teacher education program can promote ESD through a residential field course. We have seen how the field course can be an aim in itself through the student teachers' experience in being close to nature and thereby reduce a human-centred outlook on the world in which we live, but the importance of suitable pedagogies for outdoor education to make substantial impact has also been stressed.

Founded in experiential learning theory, the teacher education program includes active learning approaches, and we have seen that inquiry learning has the capability to realise most aspects of ESD. Phenomenon-based teaching is another approach which can contribute to both more pluralistic teaching and affection. The latter may, together with the social aspects emphasising a safe learning environment, in turn make the student teachers motivated for ESD and give them courage to explore the unknown.

The residential field course is arranged annually, and even though the location has changed, the field course has the same structure and the findings are transferrable. The perspective in this research has been on what is taught, and we would suggest that future research focuses on the student teachers and their outcomes of the project.

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Errata

Page number	Paragraph	Change from	Change to
85	4	Science Teacher Education for Sustainable Development – A case study of a residential field course in a Norwegian pre-service teacher education program. *Manuscript accepted for publication in Adventure Education and Outdoor Learning*.	Science teacher education for sustainable development: A case study of a residential field course in a Norwegian pre-service teacher education program. *Journal of Adventure Education and Outdoor Learning*