education sciences

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Systems Thinking for Understanding Sustainability? Nordic Student Teachers' Views on the Relationship between Species Identification, Biodiversity and Sustainable Development

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Received: 26 May 2017; Accepted: 8 September 2017; Published: 15 September 2017

Abstract: Sustainability is a complex concept including ecological, economic and social dimensions, which in turn involve several aspects that are interrelated in a complex way, such as cultural, health and political aspects. Systems thinking, which focuses on a system's interrelated parts, could therefore help people understand the complexity of sustainability. The aim of this study is to analyse student teachers' level of systems thinking regarding sustainability, especially the ecological dimension, and how they explain the relationship between species identification, biodiversity and sustainability. Nordic student teachers (*N* = 424) participated in a questionnaire and their open answers were content-analysed and categorised. The results indicate the student teachers' low level of systems thinking regarding ecological sustainability. About a quarter of them (25.4%) had a basic level including interconnections (13.7%), additional feedback (8.9%) and also behavioural aspects (2.8%), but none of them reached an intermediate or advanced level. The low level of systems thinking could be explained by two main factors: (1) Systems thinking has not been used as an educational method of developing understanding of sustainability in teacher education programmes; and (2) systems thinking is also a result of life experiences; the older ones showing more systems thinking than the younger ones. Therefore, elementary forms of systems thinking should be an educational method already in primary education.

Keywords: sustainability; biodiversity; species identification; systems thinking; teacher education

1. Introduction

> "*Sustainable development* cannot be achieved by technological solutions, political regulation or financial instruments alone. We need to change the way we think and act. This requires quality education and learning for sustainable development at all levels and in all social contexts [1]".

Sustainable development (hereafter used synonymously with *sustainability*) is a complex concept including ecological (environmental), economic and social dimensions, which in turn comprise several different aspects, all interrelated in a complex way. For example, cultural and health aspects are parts of the social dimension, and political aspects of the economic dimension. The importance of education for sustainable development (hereafter used synonymously with *sustainability education*) is often highlighted in international policy documents of education. It has been on the agenda for all stages of education since the publication of two documents: 'Brundtland report' [2], and 'Agenda 21' from the Rio de Janeiro conference [3]. Furthermore, the decade 2005–2014 was declared by UNESCO [4] as the United Nations' decade of education for sustainable development. The goal of the declaration was to promote sustainability at all levels of education. Despite all good plans and policy documents, sustainability education has not yet reached the goals for schools and higher education, according to recent research [5–10]. One reason can be the scarcity of sustainability education in teacher education worldwide [11–14]. If teachers have not had any opportunity to think, practise and develop their own understanding of sustainability during their education, they are not expected to do so in their future teaching either [14–16].

Society is still faced with a challenging paradox. Because of the economic growth and development of society towards more market-based economies, many countries have invested in education which prepares their citizens for life in a so-called global knowledge-based economy, whereas sustainability is less emphasised [17]. There is an obvious problem with this development of society, since there is a contradiction between economic growth and sustainability. Economic growth is linked to increased consumption and increased emissions in the atmosphere, which, in turn, are strongly linked to increased environmental impact [18,19]. Consumption and finances, as well as political and social systems, have either direct or indirect impact on Earth's *biodiversity*. Like many policy documents about sustainability education, there are several theories, plans and recommendations about how the education for 'sustainability citizenship' [20] should be arranged. Some of them point out critical pedagogy combined with environmental aspects and ecological politics, involving active participation of teachers and students [21,22].

The importance of integrating *systems thinking* into education has also been emphasised in order to promote understanding of the complex nature of sustainability [23,24]. Systems thinking is a holistic way of analysing how a system's constituent parts are interrelated and how the system works over time and within the context of larger systems [25,26]. Systems thinking could therefore be used to deepen people's holistic thinking about sustainability. It is important to develop a comprehensive understanding of complex casual relationships, as relationships between human systems and natural systems might be. The starting point for managing the complex understanding of sustainability is therefore to develop a holistic understanding of key ecological concepts and the role of biodiversity and species identification. Basic knowledge about species, their identification and life history are important aspects for learning and understanding biodiversity (more in Sections 1.1 and 1.2). Teachers have a central role in providing students with opportunities for understanding sustainability.

Does teacher education give student teachers the necessary tools to understand the importance of everyone's role in the system? The aim of this study is to analyse student teachers' level of systems thinking regarding sustainability, especially the ecological dimension of sustainability, and how they explain the relationship between species identification, biodiversity and sustainable development. Student teachers are university students who study education as their main subject in order to become primary-school teachers (for grades 1–6, 1–4 or 1–7). As a theoretical framework we focus on these main concepts and their role in understanding sustainability.

1.1. Species Identification and Ecological Literacy for Understanding of Sustainability

An undeniable fact is that newly qualified teachers teach about nature and science using the skills they obtained during the obligatory part of their teacher education. Knowledge of species and species' role in the ecosystem constitute an important core of biology teaching [27]. Knowledge of species and identification skills are factors which are also important in developing people's interest in environmental issues and sustainability [28,29]. It is easier to understand abstract processes in ecology when well-known species are included [30–33]. Species identification skills, an interest in nature and outdoor experiences, in turn, develop people's understanding of environmental issues and a sustainable lifestyle [28,29,34–36].

An understanding of ecological key concepts and processes helps people to see more complex relationships in the natural and human systems [36,37]. Unfortunately, the level of people's knowledge of species has decreased significantly during the past 20 years [28,29,38–41]. At the same time, also their knowledge of ecological key concepts and understanding of ecological processes have decreased [37,42–44] to such an extent that the phenomenon has been referred as *ecological illiteracy* [36,45,46].

In the 1980s *environmental literacy* was positioned as an essential goal of environmental education. This education was supposed to develop ecological knowledge, socio-political knowledge, and knowledge of environmental issues, as well as to adopt environmentally responsible behaviour [47]. The concept *ecological literacy* has been used synonymously to environmental literacy by several researchers, while for example Cutter-Mackenzie and Smith [48] emphasise the pedagogical content knowledge and fundamental ideas and approaches in environmental education as a special part of ecological literacy. A person's ecological literacy has been defined as their capacity to understand the systems in nature by understanding key ecological systems and characteristic features of ecology [49,50]. Ecological literacy could therefore form the basis of environmental sustainability as a more positive approach than focusing only on environmental problems [47,51].

The fact that Nordic student teachers possess low levels of species identification [29] and ecological knowledge [37] makes it interesting to study how they think about the relationship between species identification, biodiversity and sustainable development.

1.2. Biodiversity for Understanding of Sustainability

Biodiversity is fundamental for continuous life on Earth. It is also essential for human health and resilience [52], as well as for social and economic development [4,53]. Biodiversity means variation richness among all living organisms at three levels: 1. Genetic diversity (richness of the variety and range of genes within and between populations of organisms); 2. Species diversity (the number of species and number of individuals of each species in a particular location); and 3. Ecosystem diversity (variety of habitats, living communities, and ecological processes). These levels are also important parameters of sustainability, when reflecting the interaction of ecological, economic and social issues [3,54–58].

Biodiversity has been described as one of the major pathways to sustainability [59] and the protection of biodiversity as one of the basic roads to sustainability [60]. Therefore, basic knowledge about species, their identification and life history have been considered to be fundamental components for learning and understanding biodiversity [31,33,57,61]. Biodiversity education in turn can be seen as a model for sustainability education, while sustainability education is one instrument among others (e.g., technical innovations and restrictions by law) for achieving a sustainable future [62].

People's understanding of biodiversity, however, seems to have declined significantly during the past decades [60,62,63]. A global problem today is therefore that all three dimensions of biodiversity have been simplified and homogenised, while species extinction continues, mainly caused by human activities [64]. People take the term biodiversity to refer mostly to the animal kingdom and associate it with words connected with environmental problems [60], or, they only consider the economic values of biodiversity and nature [65]. One reason can be the significant decline in general knowledge of common organisms [29,38,41,66], but also problems in understanding what a sustainable use of biodiversity means [60].

The situation is not better regarding teachers and student teachers. Previous research reveals that they do not understand what biodiversity means and everything it includes [59,60,67–69]. It was, however, easier for student teachers to explain ecology-related concepts when they had relevant knowledge of species occurring in a habitat [70]. Magntorn's idea in learning to 'read nature' [50] is that taxonomy can be linked to systems thinking via the autecology of the species (the ecological relationships of a particular plant or animal species). Although students do not understand the complexity of biodiversity, they do, according to another study [63], have positive attitudes towards it. Previous research emphasises the importance of the preparation of student teachers in biodiversity education [61,71]. Therefore, we find it important to analyse student teachers' understanding of biodiversity, what they include in the concept and how they describe the importance of biodiversity for sustainability.

1.3. Systems Thinking for Understanding of Sustainability

Systems thinking is understood as the ability to see the world as a complex system where everything is connected to everything else [72]. It is an important factor in order to develop thinking in education. The challenge for education is to develop a pedagogy that provides individuals with knowledge about how different choices affect society [73]. Systems thinking, being the capacity of identifying various biophysical and social components in a given environmental context and the interrelations in whole systems [24], should therefore be based at least on critical thinking and reflection, deliberation and action competence [26,74]. Systems thinking is a way of thinking that helps people see their role from a holistic point of view. It is more than causal thinking, which, however, is part of systems thinking [75]. Systems thinking is focused on processes and entirety instead of parts or details [25,76]. System dynamics and systems thinking can be taught without involving sustainability, but sustainability cannot be taught without involving systems thinking [77].

The level of systems thinking can be described, and also assessed, in different ways. Draper [72] associates seven thinking skills with systems thinking: structural, dynamic, generic, operational, scientific, closed-loop, and continuum thinking, whereas Stave and Hopper [78] identify the same skills and several more as seven different levels of activities in systems thinking: recognising interconnections, identifying feedback, understanding dynamic behaviour, differentiating types of flows and variables, using conceptual models, creating simulation models, and testing policies (see Table 1). The levels of activities are based on Bloom's taxonomy [79], and they can be arranged as a continuum from a low (basic) to a high (advanced) level of systems thinking, with the next level always including the previous one. The basic level includes three levels of systems thinking, while the intermediate and advanced levels have two levels of systems thinking each.

Table 1. Skills and levels in systems thinking (Skills according to Draper [72]; levels of systems thinking, indicators and assessment according to Stave and Hopper [78]).

Skills and Their Main Contents	Levels of Systems Thinking and Indicators of Achievement that a Person Should Be Able to Do	Assessment
1. Structural thinking Understanding interrelations	1. Recognising interconnections - identify parts of a system - identify causal connections among parts - recognise that the system is made up of the parts and their connections - recognise emergent properties of the system	- list of systems parts - connections represented in words or diagrams - description of the systems in terms of its parts and connections - definition of emergent properties - description of properties the system has that the components alone do not
2. Dynamic thinking Ability to see and deduce behaviour patterns	2. Identifying feedback - recognise chains of causal links - identify closed loops - describe polarity of a link - determine the polarity of a loop	- representation of causality and loops in words or diagrams - diagram indicating polarity
3. Generic thinking Ability to observe generic system structures	3. Understanding dynamic behaviour - describe problems in terms of behaviour over time - understand that behaviour is a function of structure - explain the behaviour of a particular causal relationship or feedback loop - explain the behaviour of linked feedback loops - explain the effect of delays - infer basic structure from behaviour	- representation of a problematic trend in words or graphs - story of how problematic behaviour arises from interactions among system components - story about what will happen when one piece of the system changes - story of the causal structure likely generating a given behaviour
4. Operational thinking Understanding how things really work, not in theory	4. Differentiating types of variables and flows - classify parts of the system according to their functions - distinguish accumulations from rates - distinguish material from information flows	- table of system variables by type - types of variables with units

	- identify units of measure for variables and flows	
5. Scientific thinking Ability to quantify relations, hypothesise and test assumptions and models	5. Using conceptual models - use a conceptual model of system structure to suggest potential solutions to a problem	- story of the expected effect of an action on a given problem - justification of why a given action is expected to solve a problem
6. Closed-loop thinking Recognising internal circular causality of cause-effect feedback	6. Creating simulation models - represent relationships between variables in - mathematical terms - build a functioning model - operate the model - validate the model	- model equations - simulation model - model run - compare model output to observed behaviour
7. Continuum thinking Recognising continuous processes in real-world phenomena	7. Testing policies - identify places to intervene - within the system - hypothesize the effect of changes - use model to test the effect of changes - interpret model output with respect to problem - design policies based on model analysis	- list of policy levers - description of expected output for given change - model output - comparison of output from different hypothesis tests - policy design

Stave and Hopper [78] also developed indicators of achievement and assessment tests for the seven levels. These indicators and tests are used as a basis in the analysis of the level of the student teachers' systems thinking in this study (see Methods). Indicators of achievement also include aspects of behaviour and action, which means a wider perspective of systems thinking than only an organisational level, and for which Flood [80] therefore used the concept 'socio-ecological perspective of systems thinking'. Action orientation, learning how to act and how actions affect human and the environment in turn constitute the basis in an ecosocial approach of education for sustainable lifestyle [81,82].

2. The Aim of the Study and Research Questions

This is the second part of the Nordic-Baltic case studies of student teachers' views of species, biodiversity and sustainable development. The first part [29] provided a comprehensive review of previous research on the theme and an overview of 456 student teachers' species identification skills, their interest in and opinion of the importance of species, biodiversity and sustainable development. Because the student teachers' ability to identify very common species was low, although a majority of them regarded species identification as important or very important in general (55%) and especially for sustainable development (86%), in the same way as biodiversity was for sustainable development (92%), it is fundamental to study further, and in more detail, how the student teachers perceive the relationship between species identification, biodiversity and sustainable development. Do they describe interrelations in the complex system of sustainability? The aim of this study is to analyse student teachers' level of systems thinking regarding sustainability, especially the ecological dimension of sustainability, and how they explain the relationship between species identification, biodiversity and sustainable development.

The following research questions guided the study:

1. How do student teachers describe the relationship between species identification, biodiversity and sustainable development?
2. What level of systems thinking do student teachers' answers reflect?
3. Are there any differences in student teachers' answers with respect to their backgrounds (the country where they participated in teacher education, their gender or age)?

3. Materials and Methods

In total, 424 second- to fourth-year student teachers in three Nordic countries (225 Finnish, 68 Norwegian, and 131 Swedish) participated in the survey as volunteers. The student teachers had taken the obligatory course/courses in biology or science at least half a year before taking part in the survey. The majority of them (82%) were women, 65 percent were under 25 years old, 24 percent were aged 25–35 and 11 percent were over 35. They thus represented the typical group of student teacher by age, gender and completed obligatory studies in biology or science in the Nordic countries [29]. There were, however, some differences in students' age distribution in the three countries. The majority of the Norwegian students (81%) were under 25, while the corresponding percentages for the Finnish and Swedish students were 70 and 50. Nearly 23 percent of the Swedish students, but only 5 percent of the Finnish and 9 percent of the Norwegian students, were over 35. Age and gender were selected as probable factors affecting understanding of sustainability based on previous research, e.g., [9,15]. An interesting question was also whether the different teacher education programmes in these countries [29] have any effects on their student teachers' ways of thinking about species identification, biodiversity and sustainability.

In addition to the questions about the students' background, the survey consisted of two parts: a species identification test and a comprehensive questionnaire with fixed, multiple-choice and open questions (see more details about the total survey in [29]). All material was collected during one single session, but for this study, an open, summarising question from the questionnaire was chosen as the main question ('Describe your opinion about the relationship between species identification, biodiversity and sustainable development'). The student teachers were asked to describe their own view about the relationship between species identification, biodiversity and sustainable development. They were encouraged to use some kind of mind-map or other sketches in their answer. They could also specify their view about the importance of species identification and biodiversity for sustainable development in two additional questions. These questions were used as a complement to the main question, but also to ensure the researchers' correct interpretations of the main question.

The student teachers' answers were first coded and carefully transcribed together with possible mind-maps and sketches. The sketches and texts were then analysed mainly using inductive content analysis [83,84], but the analysis was also guided by Stave and Hopper's model of the seven levels of systems thinking (see Table 1). The analysis can therefore be considered a mix between inductive and deductive content analysis, i.e., an abductive approach in phenomenological methodology [85].

The inductive content analysis resulted in four categories. The first category, *no answer*, comprises a range of answers from a total lack of attempts to answers where students pointed out that they did not understand the question (e.g., by writing a question mark or sentences such as 'I do not know', 'I do not have enough knowledge to answer', 'I do not understand the question'). Answers where students only repeated the names of the three key concepts (species identification, biodiversity and sustainable development) without describing them are also included in this category. The second category, *answers involving nonsense or cliché*, includes answers which clearly show that students had not understood the relationship but still tried to explain something, and often used some kind of clichés. The third category, *answers involving partial relationships*, includes several kinds of answers about the key words separately, but without indicating systems thinking. The fourth category includes different kinds of systems thinking, and was further categorised according to Stave and Hopper's seven categories of systems thinking [78].

Two researchers read the transcribed answers several times making notes and headings. They then individually categorised the answers and selected descriptive examples for every category. Finally, they compared and discussed their categorising until they could agree to 100 percent. All used categories and corresponding categories in Stave and Hopper's model [78] are summarised in Table 2.

Table 2. Categories used in the analysis of the student teachers' answers about the relationship between species identification, biodiversity and sustainable development, from the lowest to the highest level of possible systems thinking.

Categories Used in This Study	Corresponding Seven Categories in Stave and Hopper's Model [78] (Descriptions in Table 1)
No level of systems thinking	
1. No answer	-
2. Answers involving nonsense or cliché	-
3. Answers involving partial relationships	-
Basic level of systems thinking	Basic level of systems thinking
4. Answers involving interconnections	1. Recognising interconnections
5. Answers involving feedback	2. Identifying feedback
6. Answers involving behavioural aspects	3. Understanding dynamic behaviour
Intermediate level of systems thinking	Intermediate level of systems thinking
7. Answers involving variables and flows	4. Differentiating types of variables and flows
8. Answers involving conceptual models	5. Using conceptual models
Advanced level of systems thinking	Advanced level of systems thinking
9. Answers involving simulation models	6. Creating simulation models
10. Answers involving policy models	7. Testing policies

In the following section we will describe the recognised categories both quantitatively and qualitatively, using rates of responses, and citations and sketches as examples from every category. The citations and sketches are word-for-word translations from Finnish, Swedish or Norwegian into English, and marked with four-digit numbers to guarantee anonymity. The first digit indicates a student's home country: (1) Finland; (2) Sweden; and (3) Norway. The three remaining digits are individual student codes. In addition, the students' gender (F = female and M = male), as well as their age (1 <25, 2 =25–35 and 3 >35 years of age) are indicated after the four-digit numbers. For example, the code 1056F1 indicates a Finnish female student teacher aged 25 or under. Differences in the student teachers' answers with respect to their background (the country in which they participated in teacher education, their gender, or age) were tested for statistical significance by Pearson Chi-Square ($p < 0.001$).

4. Results

The student teachers' answers about the relationship between the species identification, biodiversity and sustainable development were very heterogeneous, including also different views on how important they consider species identification and biodiversity are for sustainable development. According to previous research, systems thinking could be an important way to understand sustainability, and the analysis of student teachers' systems thinking is therefore the main subject here and will be described in detail. We also found differences in the levels of systems thinking depending on the country in which they participated in teacher education or their age.

4.1. Student Teachers' Systems Thinking

The results show that the student teachers have no or just a basic level of systems thinking regarding ecological sustainability. The majority of students (74.6%) showed no systems thinking in their answers about the relationship between species identification, biodiversity and sustainable development. Systems thinking was, however, used by 25.4 percent of the students, but only on a basic level (Figure 1). None of the answers reached an intermediate or advanced level of systems thinking, and all figures are therefore presented here without the categories 7–10 (c.f. Table 2).

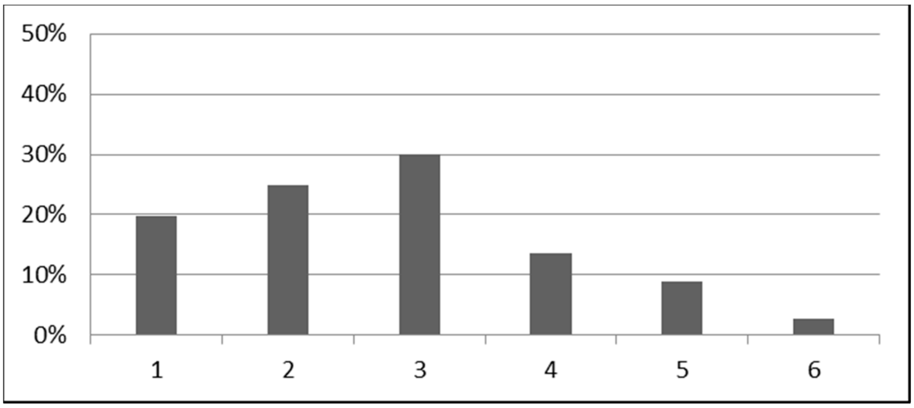

Figure 1. Student teachers' views about the relationship between species identification, biodiversity and sustainable development in six categories (1 = no answer; 2 = answers involving nonsense or cliché; 3 = answers involving partial relationships without systems thinking; 4 = answers involving interconnections; 5 = answers involving interconnections and feedback; 6 = answers involving interconnections, feedback and behavioural aspects). Note: Categories 7–10 were deleted from the figure because there were no answers in these categories.

The answers that lack systems thinking (categories 1–3) were very heterogeneous. Almost a fifth of all answers (19.8%) were placed in Category 1. In addition to many 'empty answers' the category included answers where student teachers explained why they could not answer the question, for example, that they were not familiar enough with the theme, or that they had never before thought about this kind of relationship.

Category 2 included answers with nonsense or clichés (24.8%). Nonsense answers, in this study, were answers which denied, or described something else than the relationship between or about the three given concepts. For example, a female student teacher, who considered biodiversity to be 'neither important nor unimportant' for sustainable development, expressed the relationship in this way: "In my opinion there is no such immediate relationship between these (concepts). Or in my own mind I think of them as separate classes, which I cannot connect" (1135F1). Some other student teachers named only food and protection. A female student, for example, ticked the alternatives 'very important' and 'important' for the importance of species identification respectively biodiversity for sustainable development, and explained the relationship in this way: "If you know plants and animals, you do not eat protected species" (1015F1). Another female student, who claimed to be interested in nature, wrote: "I'm not so familiar with small animals. Big animals, however, I think are important. Birds and frogs are not that important, are they? Snakes and reptiles are disgusting. I think [the relationship] is not that important. If an animal is meant to live, nature itself will take care of it (…)" (2081F1). There were also answers which were more like clichés than explanations: "The relationship is important, for us and for the future" (2093F1). The cycle must function and all species have a part in it" (2056F3). What exactly they meant, is unclear, because they did neither explain the importance of species identification nor biodiversity for sustainable development.

Category 3 (30% of the answers) consisted of answers involving many clear and important descriptions of some or all of the three given concepts, but lacking systems thinking. For example, a female student described the relationship in this way: "The three things are related because we humans need knowledge of species in order to maintain diversity. In a society with sustainable development, one must have knowledge of the species" (3049F1). Another female student explained the relationship in the following way: "The relationship is that if one is aware of the plants and animals one can contribute to sustainable development, which means that you are extra careful how you for example choose to deal with nature" (2059F1). Another student pointed out that: "If you want to have a deeper understanding, the importance of species identification increases. Species identification can help you appreciate biodiversity. A decrease in biodiversity makes the living environment and the whole earth more vulnerable. Development, which destroys biodiversity, cannot be sustainable" (1145F3). This category also comprises very short answers where student teachers named some details or topics that are relevant for the relationship, but without explaining how these are connected. Such topics were: endangered species and nature conservation; protection of biodiversity; edible and poisonous species; usefulness and wholesomeness of species for man; sufficiency of food; food chains and webs; indicators of the balance in nature; interest-increasing knowledge; knowledge and a need to do more for protection; knowledge to be familiar with and to appreciate one's own neighbourhood; the development of the relationship to nature.

Answers in categories 4–6 (25.4%) included systems thinking on a basic level. Student teachers in Category 4 (13.7%) recognised interconnections in the relationship between species identification, biodiversity and sustainable development. The relationship was described by a student in this way: "It is important to be able to give names to the species, (and) then it is much easier to register when someone may be missing. Biodiversity is the diversity of species which can most likely ensure sustainable development" (3026M2). Another student put it this way: "Species identification: becoming aware of diversity. Biodiversity: getting a greater understanding. Sustainable development: everything is connected to everything else and even mosquitoes are needed" (2025F3). Some students described the relationship using a concept map, for example this student (1086M1) (Figure 2).

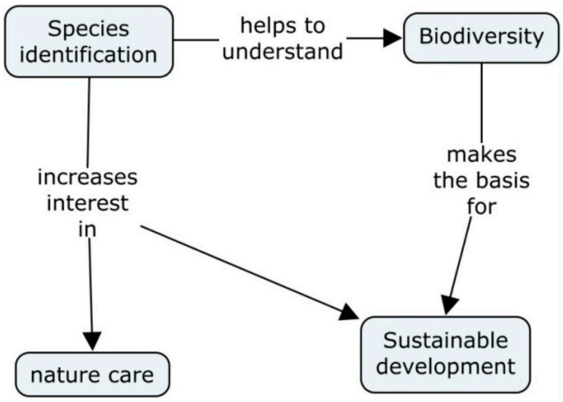

Figure 2. Example of a student's answer as a concept map in Category 4.

Category 5 comprised 8.9 percent of all answers. It included interconnections and additional feedback loops in the described relationships between species identification, biodiversity and sustainable development. A female student produced the following: "All parts of nature are interconnected. If one part disappears, many other parts also disappear. Biodiversity is very important and species identification too is very important for understanding the entirety" (1070F2). Another student explained it by first drawing a loop between the three concepts: biodiversity—species identification—sustainable development, and then explained: "All are interconnected, a 'cause and effect'-relationship; it is good to start from species identification for understanding the biodiversity of the organisms, which in turn affects sustainable development positively. All organisms have their place and meaning, and therefore biodiversity is very important" (…) (1167F3).

Category 6 included also behavioural aspects in addition to interconnections and feedback loops. Only 2.8 percent of the answers were placed in this category. Typical for this category was that all answers included some of the words or meanings: 'choices affect', 'consequences of actions' or 'everything is connected'. Two examples describe this category:

> "Man should base their actions in accordance with the principles of sustainable development. Since our actions do anyway cause changes in nature, the bigger the biodiversity, the better nature can handle it on the whole. When we know species, we can also perceive the biodiversity of nature, and can therefore better notice the consequences of our actions, [and] appreciate every species as an important part of the big picture (…)" (1182F3).

> "Individual species are important for the diversity of living organisms. We use resources so that nature can stay varied and functional. Then we also take care of individual species, know their needs and habitats, and do not destroy species 'by mistake'. Sustainable development: if we take care of comprehensiveness by protecting individual species, our own species remains viable on a viable planet (…)" (1027F3).

Descriptive examples of the categories were mostly given only in words, but the original answers often also included some kind of sketches, where the three key words were 'correctly' placed but not always explained.

4.2. Differences between Finnish, Norwegian and Swedish Student Teachers' Answers

There were several differences between the answers given in the three participating countries. The Finnish student teachers used basic systems thinking much more than their Norwegian and Swedish colleagues when describing the relationship between species identification, biodiversity and sustainable development. About a third of the Finnish answers (34.2%) were placed in categories with systems thinking (categories 4–6), while the corresponding percentages for Norwegian and Swedish answers were 13.3 and 16.8 (Figure 3).

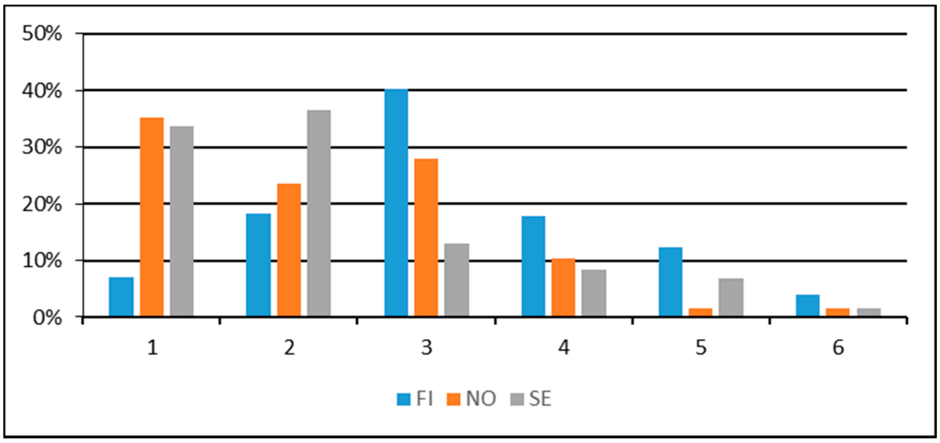

Figure 3. A comparison of Finnish (FI), Norwegian (NO) and Swedish (SE) students' views about the relationship between species identification, biodiversity and sustainable development in six categories (1 = no answer; 2 = answers involving nonsense or cliché; 3 = answers involving partial relationships without systems thinking; 4 = answers involving interconnections; 5 = answers involving interconnections and feedback; 6 = answers involving interconnections, feedback and behavioural aspects). Note: Categories 7–10 were deleted from the figure because there were no answers in these categories.

Only 7.1 percent of the Finnish teacher students did not answer or did not understand the question (Category 1), in contrast with 35.3 respectively 33.6 percent of the Norwegian and Swedish students. The most frequent category for the Finnish students was Category 3 (40.4%), Category 1 (35.3%) for the Norwegian students and Category 2 for the Swedish students. The differences between the countries were statistically significant (Pearson Chi-Square (10, $N = 424$) = 87.7718, $p = 0.000$).

4.3. Gender Differences

There were some differences in the answers as far as gender is concerned. 31.6 percent of the male student teachers showed basic systems thinking (categories 4–6), while the corresponding percentage for the females were 24.1 (Figure 4). However, only 5.3 percent of the males and 2.3 percent of the females described the relationship between species identification, biodiversity and sustainable development using the highest basic level of systems thinking, including interconnections, feedback and behavioural aspects (Category 6).

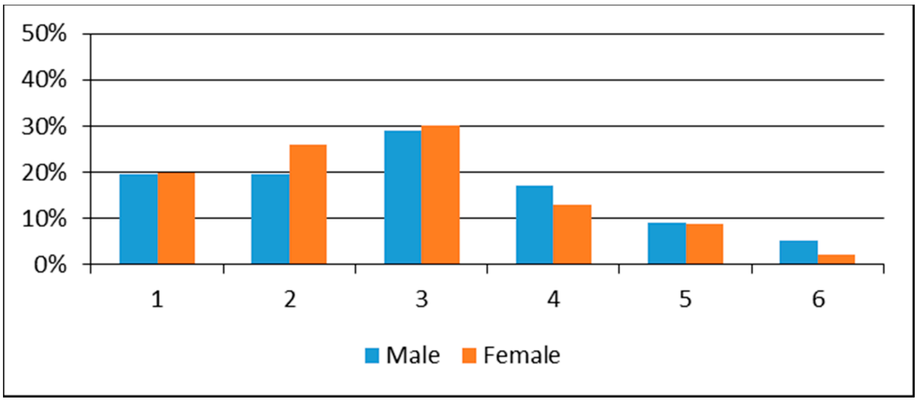

Figure 4. A comparison of female and male student teachers' views about the relationship between species identification, biodiversity and sustainable development in six categories (1 = no answer; 2 = answers involving nonsense or cliché; 3 = answers involving partial relationships without systems thinking; 4 = answers involving interconnections; 5 = answers involving interconnections and feedback; 6 = answers involving interconnections, feedback and behavioural aspects). Note: Categories 7–10 were deleted from the figure because there were no answers in these categories.

The gender differences were not, however, statistically significant (Pearson Chi-Square (5, $N = 424$) = 3.714, $p = 0.591$).

4.4. Differences between Age Groups

Another interesting factor is how age, and thus life experience, affects student teachers' ways of understanding and describing the relationship between species identification, biodiversity and sustainable development. To study this, the descriptions were studied regarding three age groups of student teachers: those under 25 years, those aged 25–35, and those over 35 years of age. Descriptions produced by the age group under 25 were mostly found in categories 1, 2 and 3 (78.9%), whereas systems thinking only existed in 21.1 percent of their answers. The corresponding percentage for age group 25–35 was 35.4 and that for those over 35 was 31.3 (Figure 5).

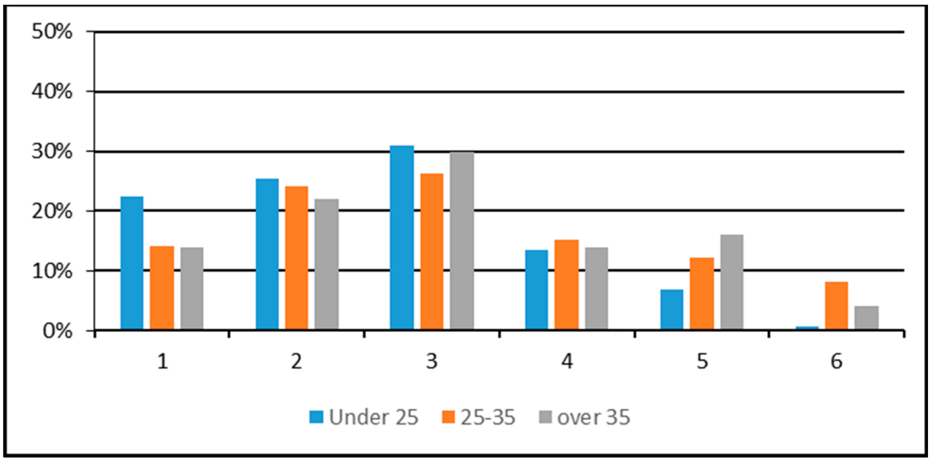

Figure 5. A comparison of student teachers' views about the relationship between species identification, biodiversity and sustainable development in three age groups (<25; 25–35; >35) and six categories (1 = no answer; 2 = answers involving nonsense or cliché; 3 = answers involving partial relationships without systems thinking; 4 = answers involving interconnections; 5 = answers involving interconnections and feedback; 6 = answers involving interconnections, feedback and behavioural aspects). Note: Categories 7–10 were deleted from the figure because there were no answers in these categories.

The differences between the age groups were statistically significant (Pearson Chi-Square (10, $N = 422$) = 22.472, $p = 0.013$).

5. Discussion and Conclusions

In this study, focus was directed towards student teachers' systems thinking about the ecological dimension of sustainability, and especially their views about the relationship between species identification, biodiversity and sustainable development. According to previous research [28,29,33], knowledge of species and species identification skills are important factors in developing people's interest in environmental issues and sustainability. Furthermore, an understanding of ecological key concepts, such as biodiversity, helps people to see and understand more complex relationships in natural systems [36,37], especially if also well-known species [32,33] and nature experiences are included [34,35,86]. People's ability to identify the separate components in ecological sustainability however, is only a starting point. Systems thinking could therefore help them to identify and understand how everything is connected to everything else in the complex system of sustainability [24]. As far as we know, however, there are no major investigations of people's level of systems thinking concerning sustainability. This study contributes to the improving of the situation in several ways. Firstly, it investigated the level of systems thinking regarding one complex dimension of sustainability, i.e., ecological sustainability. Secondly, it studied a large group of student teachers from three countries who are future primary-school teachers, and therefore have a central role in the education of sustainability in the Nordic countries. Moreover, this study describes the actual level of student teachers' understanding of ecological sustainability, which can be used as a base for further development of sustainability in teacher education programmes. Education is seen as a key strategy to help people understand the complexity of sustainability, which in turn could help them to make more sustainable lifestyle decisions [15,24].

Because the majority of student teachers (about 75%) did not show any signs of systems thinking when describing ecological sustainability, systems thinking as an educational method seems not to have been used very much in teacher education programmes. Furthermore, there was a statistically significant difference between the three age groups; the older ones (25–35 and >35) showing more systems thinking than the younger ones (<25), especially when it comes to the Norwegian student teachers. This indicates that their systems thinking could be more a result of life experiences than that of education. On the other hand, there are several reports of teacher education programmes that totally lack, or have only few, sustainability subjects [12–14,87,88]. The student teachers' low level of systems thinking in ecological sustainability also reflects minor volumes of nature studies and ecological aspects among the more extensive pedagogical and other subject studies in teacher education [37,44,70,72].

The low level of student teachers' systems thinking and the many insufficient answers in the two lowest categories, nearly half of all answers (44.6%), could hardly depend on a methodological factor. The main question of this study ('Describe your opinion about the relationship between species identification, biodiversity and sustainable development') was placed as the last question of the survey because of its summarising character. This means that some student teachers might have left this particular question unanswered because of time constraints or that they did not put too much effort answering the question in a very detailed way, because of loss of interest or energy. However, the two former questions, which dealt specifically with the importance of species identification and biodiversity for sustainable development, also had corresponding deficiencies. Several of the student teachers wrote that they had never thought of this kind of relationship or that they did not know enough to be able to answer the question. Some of them just wrote anything to fill the empty space or, even worse, had no idea of what the question was all about. Because the answers were anonymous, further interviews with these students were unfortunately impossible.

There are several studies [36,37,42,60] which point out that many student teachers (such as those in this study) do not understand the key concepts of ecology. One of the most important key concepts is biodiversity. However, people's understanding of biodiversity, and particularly the importance of biodiversity for sustainability, is often incomplete and includes misunderstandings [60–63]. In this study, and our previous study [29], most of the student teachers considered biodiversity to be important or very important for sustainable development, but many of them could not explain why. Their views of the importance of species identification for sustainable development may explain something of their difficulties to understand biodiversity. They perceived species as either useful or harmful to themselves (e.g., eatable or poisonous), not as an important part of the whole. This anthropocentric view and economic valuation of nature are often given priority compared to other types of values, and can therefore threaten biodiversity conservation and sustainability [65]. It is, therefore, important to include other values and also emotional aspects in sustainability education [89]. Student teachers need to develop their understanding of ecological key concepts at the latest in teacher education, in order to avoid spreading their own misconceptions as teachers.

Another interesting fact is that there was a statistically significant difference in the levels of systems thinking between student teachers from the different countries. The Finnish student teachers had a higher percentage of basic systems thinking than their Norwegian or Swedish colleagues. In fact, the same group of Finnish student teachers also had better species identification skills (detail knowledge) than the corresponding groups of Norwegian and Swedish students in our previous study [29]. However, the differences are small and cannot be explained only by the differences in the respective country's teacher education programme, or by the different number of participating students from the three countries. In addition, there exist several studies where Finnish teacher education is criticised for failing in sustainability [9,14,87]. The Finnish programme for teacher education for primary schools is, however, very attractive and draws many more applicants than the corresponding Norwegian or Swedish programmes [88], which is why only high-performance students are accepted. Teacher education authorities in these countries probably follow the same recommendation from Unesco [90] in order to implement sustainability in teacher education. Sustainability is strongly connected to ecological literacy and also value-dependent, and applications of sustainability are therefore complicated [14]. Education of good quality requires teachers to have knowledge and skills to be able to plan and carry out meaningful teaching [91]. Student teachers may find it difficult to teach about sustainability and all its dimensions and aspects. They need training in sustainability education, which has also been suggested in many other studies [13,14,87,92].

The results of this study showed that the majority of student teachers in Finland, Norway and Sweden have not developed any form of systems thinking through their education. It is also obvious that those student teachers who have a basic level of systems thinking, have developed it mainly through their own life experiences. Systems thinking needs to be incorporated in the education of teachers, because there is a necessity to develop an educational programme that provides individuals with knowledge about how different actions and choices affect the whole society. In other words, teacher education programmes should include such a form of systems thinking that is based on critical thinking, negotiation and action competence. Sustainability cannot be taught without involving systems thinking [23,77].

Since systems thinking is a way of thinking the starting point is to focus more on the process than the content of teaching. Instead of education which is limited to instruction and transfer of knowledge, education should comprise dynamic, activity-based and participatory training based on generating knowledge and meaning in relation to the circumstances in the local society and the world. Problem-solving in such education is thus based on real events [74]. Integrating systems thinking in sustainable education in teacher education can be made by using interdisciplinary and multidisciplinary projects, where the main goal is to make participants think in holistic ways by identifying and analysing possible components in their project, and then critically reflect on how everything is connected to everything else in the complex system. Since systems thinking is also a result of life experiences, elementary forms of systems thinking should be an educational method already in primary education.

Acknowledgments: Our thanks go to our colleagues in Finland, Norway and Sweden for their help with collecting the material. The following foundations have supported the research: Högskolestiftelsen i Österbotten, Svenska Kulturfonden and Aktiastiftelsen.

Author Contributions: Irmeli Palmberg is the responsible project leader and wrote all sections of this paper. Irmeli Palmberg, Eila Jeronen and Eija Yli-Panula designed and carried out the survey. Irmeli Palmberg and Maria Hofman-Bergholm analysed and categorised the material, and Maria Hofman-Bergholm made the statistical analyses. All authors checked and commented on the manuscript after the language check.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. UNESCO. Education for Sustainable Development. 2017. Available online: http://en.unesco.org/themes/education-sustainable-development (accessed on 15 March 2017).
2. Wolff, L-A.; Sjöblom, P.; Hofman-Bergholm, M.; Palmberg, I. High performance education fails in sustainability? – A reflection on Finnish primary teacher education. *Educ. Sci.* **2017**, *7*, 1–22, doi: 10.3390/educsci7010032.
3. WCED (World Commission on Environment and Development). *Our Common Future*; University Press: Oxford, UK, 1987.
4. UNCED (United Nations Conference on Environment and Development). The Final Text of Agreements Negotiated by Governments at United Nation's Conference on Environment and Development, In Agenda 21: Programme of Action for Sustainable Development: Rio Declaration on Environment and Development; Statement of Forest Principles. In Proceedings of the UNCED (United Nations Conference on Environment and Development), Rio de Janeiro, Brazil, 3–14 June 1992; United Nations Department of Public Information: New York, USA, 1993.
5. UNESCO (United Nations Educational, Scientific and Cultural Organization). *UN Decade of Education for Sustainable Development 2004–2005*; UNESCO: Paris, France, 2005.
6. Alexandar, R.; Poyyamoli, G. The Effectiveness of environmental education for sustainable development based on active teaching and learning at high school level—A case study from Puducherry and Cuddalore regions, India. *JSE* **2014**, *7*. Available online: http://www.jsedimensions.org/wordpress/content/the-effectiveness-of environmental-educationfor-sustainable-development-based-on-active-teaching-and-learning-at-high-school-level-a-case-studyfrom-puducherry-and-cuddalore-regions-india_2014_12/ (accessed on 27 May 2016).
7. Amaral, L.P.; Martins, N.; Gouveia, J.B. Quest for a sustainable university: A review. *Int. J. Sustain. High. Educ.* **2015**, *16*, 155–172, doi:10.1108/IJSHE-02-2013-0017.
8. Beringer, A.; Adomßent, M. Sustainable university research and development: Inspecting sustainability in higher education research. *Environ. Educ. Res.* **2008**, *14*, 607–623.
9. Olsson, D.; Gericke, N.; Chang Rundgren, S.-N. The effect of implementation of education for sustainable development in Swedish compulsory schools—Assessing pupils sustainability consciousness. *Environ. Educ. Res.* **2016**, *22*, 176–202, doi:10.1080/13504622.2015.1005057.
10. Pathan, A.; Bröckl, M.; Oja, L.; Ahvenharju, S.; Raivio, T. Kansallisten Kestävää Kehitystä Edistävien Kasvatuksen Ja Koulutuksen Strategioiden Toimeenpanon Arviointi. [Evaluation of the Implementation of the Strategies on Education for Sustainable Development]. Gaia Consulting Oy, Helsinki, 2012. Available online: http://www.ym.fi/download/noname/%7B7A0AC771-670C-48B8-B7F8-8FB0B173236F%7D/78365 (accessed on 20 Mars 2017).
11. Scott, W.; Gough, S. Sustainable development within UK higher education: Revealing tendencies and tensions. In *Education for Sustainable Development*. *Papers in Honour of the United Nations Decade of Education for Sustainable Development (2005–2014)*; Chalkley, B., Haigh, M., Higgitt, D., Eds.; Routledge: London, UK, 2009; pp. 141–153.
12. Àlvarez-Garcia, O.; Sureda-Negre, J.; Comas-Forgas, R. Environmental education in pre-service teacher training: A literature review of existing evidence. *JTEFS* **2015**, *17*, 72–85.
13. Borg, C.; Gericke, N.; Höglund, H.-O.; Bergman, E. The barriers encountered by teachers implementing education for sustainable development: Discipline bound differences and teaching traditions. *Res. Sci. Technol. Educ.* **2012**, *30*, 185–207.
14. Falkenberg, T.; Babiuk, G. The status of education for sustainability in initial teacher education programmes: A Canadian case study. *Int. J. Sustain. High. Educ.* **2014**, *15*, 418–430.
15. Birdsall, S. Measuring student teachers' understandings and self-awareness of sustainability. *Environ. Educ. Res.* **2014**, *20*, 814–835.

16. Borg, C.; Gericke, N.; Höglund, H.-O.; Bergman, E. Subject-and experience-bound differences in teachers' conceptual understanding of sustainable development. *Environ. Educ. Res.* **2014**, *20*, 526–551.
17. Stevenson, R.B. Schooling and environmental/sustainability education: From discourses of policy and practice to discourses of professional learning. *Environ. Educ. Res.* **2007**, *13*, 265–285.
18. IPCC. *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2014.
19. Stern Review on the Economics of Climate Change. 2006. Available online: http://www.sternreview.org.uk (accessed on 20 January 2017).
20. Dobson, A. *Sustainability Citizenship*; Greenhouse, London, UK, 2011.
21. Huckle, J.; Wals, A.E.J. The UN decade of education for sustainable development: Business as usual in the end. *Environ. Educ. Res.* **2015**, *21*, 491–505, doi:10.1080/13504622.2015.1011084.
22. Kahn, R. *Critical Pedagogy, Ecoliteracy and the Planetary Crisis: The Ecopedagogy Movement*; Peter Lang: New York, NY, USA, 2010.
23. Lewis, E.; Mansfield, C.; Baudains, C. Ten tonne plan: Education for Sustainability from a whole systems thinking perspective. *Appl. Environ. Educ. Commun.* **2014**, *13*, 128–141, doi:10.1080/1533015X.2014.950890.
24. Sterling, S. Whole Systems Thinking as a Basis for Paradigm Change in Education: Explorations in the Context of Sustainability. 2003. Available online: http://www.bath.ac.uk/cree/sterling/sterlingthesis.pdf (accessed on 20 January 2017).
25. Bunge, M. Systemism: The alternative to individualism and holism. *J. Socio-Econ.* **2000**, *29*, 147–157.
26. Sterling, S. Sustainable Education. In *Science, Society and Sustainability: Education and Empowerment for an Uncertain World*; Gray, D., Colucci-Gray, L., Camino, E., Eds.; Routledge: New York, NY, USA, 2009; pp. 105–118.
27. Mayr, E. *What Makes Biology Unique? Considerations of the Autonomy of a Scientific Discipline*; Cambridge University Press: Cambridge, UK, 2004.
28. Palmberg, I.; Artkännedom och artintresse hos blivande lärare för grundskolan. *NorDiNa Nord. Stud. Sci. Educ.* **2012**, *8*, 244–257.
29. Palmberg, I.; Berg, I.; Jeronen, E.; Kärkkäinen, S.; Norrgård-Sillanpää, P.; Persson, C.; Vilkonis, R.; Yli-Panula, E. Nordic–Baltic student teachers' identification of and interest in plant and animal species: The importance of species identification and biodiversity for sustainable development. *J. Sci. Teach. Educ.* **2015**, *26*, 549–571.
30. Helldén, G.; Helldén, S. Students' early experiences of biodiversity and education for sustainable future. *Nord. Stud. Sci. Educ.* **2008**, *4*, 123–131.
31. Lindemann-Matthies, P. "Loveable" mammals and "lifeless" plants: How children's interest in common local organisms can be enhanced through observation of nature. *IJSE* **2005**, *27*, 655–677.
32. Magntorn, O.; Helldén, G. Reading nature from a "bottom-up" perspective. *JBE* **2007**, *41*, 68–75.
33. Randler, C. Teaching species identification—A prerequisite for learning biodiversity and understanding ecology. *Eurasia J. Math. Sci. Technol. Educ.* **2008**, *4*, 223–231.
34. Palmberg, I.; Kuru, J. Outdoor activities as a basis for environmental responsibility. *JEE* **2000**, *31*, 32–36.
35. Palmer, J.A.; Suggate, J.; Robottom, I.; Hart, P. Significant life experiences and formative influences on the development of adults' environmental awareness in the UK, Australia and Canada. *Environ. Educ. Res.* **1999**, *5*, 181–200.
36. Puk, T.G.; Stibbards, A. Systemic ecological illiteracy? Shedding light on meaning as an act of thought in higher learning. *Environ. Educ. Res.* **2012**, *18*, 353–373.
37. Palmberg, I.; Jonsson, G.; Jeronen, E.; Yli-Panula, E. Blivande lärares uppfattningar och förståelse av baskunskap i ekologi i Danmark, Finland och Sverige. *NorDiNa Nord. Stud. Sci. Educ*. **2016**, *12*, 197–217.
38. Balmford, A.; Clegg, L.; Coulson, T.; Taylor, J. Why conservationists should heed pokemon. *Science* **2002**, *295*, 2367.
39. Bebbington, A. The ability of A-level students to name plants. *JBE* **2005**, *39*, 63–67.
40. Kaasinen, A. Kasvilajien Tunnistaminen, Oppiminen ja Opettaminen Yleissivistävän Koulutuksen Näkökulmasta. [Plant Species Recognition, Learning and Teaching from Viewpoint of General Education]. Dissertation Thesis, Helsingin yliopisto, Käyttäytymistieteellinen tiedekunta, Soveltavan kasvatustieteen laitos, Tutkimuksia, Helsinki, Finland, 2009; Volume 306.
41. Randler, C. Pupils' factual knowledge about vertebrate species. *JBSE* **2008**, *7*, 48–54.

42. Krall, R.M.; Lott, K.H.; Wymer, C.L. Inservice elementary and middle school teachers' conceptions of photosynthesis and respiration. *JTE* **2009**, *20*, 41–55.
43. Pe'er, S.; Goldman, D.; Yavetz, B. Environmental literacy in teacher training: Attitudes, knowledge, and environmental behavior of beginning students. *JEE* **2007**, *39*, 45–59.
44. Zak, K.M.; Munson, B.H. An exploratory study of elementary preservice teachers' understanding of ecology using concept maps. *JEE* **2008**, *39*, 32–46.
45. Jucker, R. *Our Common Illiteracy: Education as if the Earth and People Mattered*; Environmental Education, Communication and Sustainability; Peter Lang: Frankfurt am Main, Germany, 2002; Volume 10.
46. Orr, D.W. *Ecological Literacy: Education and the Transition to a Postmodern World*; State University of New York Press: Albany, NY, USA, 1992.
47. McBride, B.B.; Brewer, C.A.; Berkowitz, A.R.; Borrie, W.T. Environmental literacy, ecological literacy, ecoliteracy: What do we mean and how did we get here? *Ecosphere* **2013**, *4*, 67.
48. Cutter-Mackenzie, A.; Smith, R. Ecological literacy: The "missing paradigm" in environmental education (part one). *Environ. Educ. Res.* **2003**, *9*, 497–524.
49. Berkowitz, A.R.; Ford, M.F.; Brewer, C.A. A framework for integrating ecological literacy, civics literacy, and environmental citizenship in environmental education. In *Environmental Education and Advocacy: Changing Perspectives of Ecology and Education*; Johnson, E.A., Mappin, M.J., Eds.; Cambridge University Press: New York, NY, USA, 2005; pp. 227–266.
50. Magntorn, O. Reading Nature: Developing Ecological Literacy through Teaching. Studies in Science and Techology Education; Dissertation Thesis, Department of Social and Welfare Studies, Linköping University, Norrköping, Sweden, 2007; Volume 6.
51. Fleischer, S. Emerging beliefs frustrate ecological literacy and meaning-making for students. *CSSE* **2011**, *6*, 235–241.
52. Sala, O.E.; Mayerson, L.A.; Parmesan, C. (Eds.) *Biodiversity Change and Human Health: From Ecosystem Services to Spread of Diseases*; SCOPE 69; Island Press: Washington, DC, USA, 2009.
53. UNESCO. Learning about Biodiversity—Multiple-Perspective Approaches; Education for Sustainable Development in Action. Learning and Training Tools, 6; UNESCO Education Sector. United Nations Decade of Education for Sustainable Development (2005–2014), UNESCO: 2014. Available online: http://unesdoc.unesco.org/images/0023/002311/231155e.pdf (accessed on 15 March 2017).
54. Van Weelie, D.; Wals, A.E.J. Making biodiversity meaningful through environmental education. *IJSE* **2002**, *24*, 1143–1156.
55. Dreyfus, A.; Wals, A.; van Weelie, D. Biodiversity as a postmodern theme for environmental education. *CJEE* **1999**, *4*, 155–75.
56. Menzel, S.; Bögeholz, S. The loss of biodiversity: How do students in Chile and Germany perceive resource dilemmas and what solutions do they see? *RISE* **2009**, *39*, 429–447.
57. Gaston, K.J.; Spicer, J.I. *Biodiversity*; Blackwell: Oxford, UK, 2004.
58. Kassas, M. Environmental education: Biodiversity. *Environmentalist* **2002**, *22*, 345–351.
59. Gayford, C. Biodiversity education: A teacher's perspective. *Environ. Educ. Res.* **2000**, *6*, 347–362.
60. Dikmenli, M. Biology student teachers' conceptual frameworks regarding biodiversity. *Education* **2010**, *130*, 479–489.
61. Lindemann-Matthies, P.; Constantinou, C.; Lehnert, H.-J.; Nagel, U.; Raper, G.; Kadji-Beltran, C. Confidence and perceived competence of preservice teachers to implement biodiversity education in primary schools—Four comparative case studies from Europe. *IJSE* **2011**, *33*, 2247–2273.
62. Lude, A. The spirit of teaching ESD—Biodiversity in educational projects. In *Biodiversity in Education for Sustainable Development—Reflection on School-Research Cooperation*; Ulbrich, K., Settele, J., Benedict, F.F., Eds.; Pensoft Publishers: Moscow, Russia, 2010; pp. 17–29.
63. Nisiforou, O.; Charalambides, A.G. Assessing undergraduate university students' level of knowledge, attitudes and behaviour towards biodiversity: A case study in Cyprus. *IJSE* **2012**, *34*, 1027–1051.
64. Speth, J.G. *The Bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability;* Yale University Press: New Hawen, CT, USA, 2008.
65. Kopnina, H. Forsaking Nature? Contesting 'Biodiversity' through competing discourses of sustainability. *J. Educ. Sustain. Dev.* **2013**, *7*, 51–63.
66. Randler, C. Animal related activities as determinants of species knowledge. *Eurasia J. Math. Sci. Technol. Educ.* **2010**, *6*, 237–243.

67. Dresner, M. Teachers in the woods: Monitoring forest biodiversity. *JEE* **2002**, *34*, 26–31.
68. Summers, M.; Kruger, C.; Childs, A.; Mant, J. Primary school teachers' understanding of environmental issues: An interview study. *Environ. Educ. Res.* **2000**, *6*, 293–312.
69. Summers, M.; Kruger, C.; Childs, A.; Mant, J. Understanding the science of environmental issues: Development of a subject knowledge guide for primary teacher education. *IJSE* **2001**, *23*, 33–53.
70. Magntorn, O.; Helldén, G. Student-teachers' ability to read nature: Reflections on their own learning in ecology. *IJSE* **2005**, *27*, 1229–1254.
71. Lindemann-Matthies, P.; Constantinou, C.; Junge, X.; Köhler, K.; Mayer, J.; Nagel, U.; Raper, G.; Schüle, D.; Kadji-Beltran, C. The integration of biodiversity education in the initial education of primary school teachers: Four comparative case studies from Europe. *Environ. Educ. Res.* **2009**, *15*, 17–37.
72. Draper, F. A proposed sequence for developing systems thinking in a grades 4–12 curriculum. *Syst. Dyn. Rev.* **1993**, *9*, 207–214.
73. Salonen, A.O. Kestävä Kehitys Globaalin Ajan Hyvinvointiyhteiskunnan Haasteena. [Sustainable Development and its Promotion in a Welfare Society in Global Age]. Dissertation Thesis, Helsingin yliopiston Tutkimuksia, Helsinki, Finland, 2010; Volume 318.
74. Hofman, M. What is an education for sustainable development supposed to achieve—A question about what, how and why. *J. Educ. Sustain. Dev.* **2015**, *9*, 213–228.
75. Sheehy, N.; Wylie, J.; McGuinnes, C.; Orchard, G. How children solve environmental problems: Using computer simulations to investigate systems thinking. *Environ. Educ. Res.* **2000**, *6*, 109–126.
76. Blewitt, J. *Understanding Sustainable Development*; Earthscan: London, UK, 2008.
77. Cloud, J.P. Some systems thinking concepts for environmental educators during the decade of education for sustainable development. In *Education for Sustainable Development*; Chalkley, B., Haigh, M., Higgitt, D., Eds.; Routledge: New York, NY, USA, 2009; pp. 225–229.
78. Stave, K.A.; Hopper, M. What Constitutes Systems Thinking? A Proposed Taxonomy. In Proceeedings of the 25th International Conference of the System Dynamics Society, Boston, MA, USA, 29 July–2 August 2007. Available online: https://www.systemdynamics.org/conferences/2007/proceed/papers/STAVE210.pdf (accessed on 20 January 2017).
79. Krathwohl, D.R. A revision of Bloom's taxonomy: An overview. *TIP* **2002**, *41*, 212–218.
80. Flood, R.L. The relationship of 'Systems thinking' to action research. *SPAR* **2010**, *23*, 269–284.
81. Salonen, A. An ecosocial approach in education. In *Schooling for Sustainable Development: Concepts, Policies and Educational Experiences of the End of the UN Decade of Education for Sustainable Development*; Jucker, R., Mathar, R., Eds.; Springer: Berlin/Heidelberg, Germany, 2014; pp. 231–233.
82. Salonen, A.; Konkka, J. An ecosocial approach to well-being: A solution to the wicked problems in the era of Anthropocene. *Foro Educ.* **2015**, *13*, 19–34.
83. Creswell, J.W. *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*; Pearson Prentice Hall: Upper Saddle River, USA, 2008.
84. Elo, S.; Kyngäs, H. The quantitative content analysis process. *JAN* **2008**, *62*, 107–115, doi:10.1111/j.1365-2648.2007.04569.x.
85. Tuomi, J.; Sarajärvi, A. *Laadullinen Tutkimus ja Sisällönanalyysi. [Qualitative Analysis and Content Analysis]*; Tammi: Helsinki, Finland, 2009.
86. Bögeholz, S. Nature experience and its importance for environmental knowledge, values and action: Recent German empirical contributions. *Environ. Educ. Res.* **2006**, *12*, 65–84.
87. Hofman, M. Hållbar utveckling i den finländska lärarutbildningen—Politisk retorik eller verklighet? 2012. Available online: https://www.doria.fi/bitstream/handle/10024/134034/MariaHofman_lic.pdf?sequence=1 (accessed on 15 January 2012)
88. Rasmussen, J.; Dorf, H. Challenges to Nordic teacher education programmes. In *Advancing quality cultures for Teacher Education in Europe: Tensions and Opportunities*; Hudson, B., Zgaga, P., Åstrand, B., Eds.; Umeå School of Education, Umeå University: Umeå, Sweden, 2010; pp. 51–67, doi:10.1080/00313831.2012.726274.
89. Ojala, M. Emotional awareness. On the importance of including emotional aspects in education of sustainable development (ESD). *J. Educ. Sustain. Dev.* **2013**, *7*, 167–182.
90. UNESCO. Guidelines and Recommendations for Reorienting Teacher Education to Address Sustainability. Education for Sustainable Development in Action, Technical Paper, 2005. Available online: http://unesdoc.unesco.org/images/0014/001433/143370E.pdf (accessed on 20 January 2017).

91. Abell, S.K. Research on science teacher knowledge. In *Research on Science Teacher Education*; Abell, S.K., Lederman, N.G., Eds.; Routledge: New York, NY, USA, 2007; pp. 1105–1149.
92. Uitto, A.; Saloranta, S. Subject teachers as educators for sustainability: A survey study. *Educ. Sci.* **2017**, *7*, doi:10.3390/educsci7010008.