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READING NATURE

Developing ecological literacy through teaching

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Studies in Science and Technology Education (FontD)

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ABSTRACT

In this study the concept *reading nature* and its contribution to science education is discussed. Some scientific concepts relevant for *reading nature* are defined. *Reading nature* has to do with the ability to recognise organisms and relate them to other organisms and to material cycling and energy flow in the specific habitat which is to be read. It has to do with authenticity where the natural world that we face outside is the book to be read and the tools we have are our experiences from previous learning situations both in and out-of-doors. The data in the study is based on the following student groups; student teachers, primary students in years 3-4 and secondary students in years 7-8. Finally a group of experienced teachers have contributed with data regarding their views on *reading nature* as a goal in science education.

The aims of the study are to describe how the ability to *read nature* can develop among the different student groups and to extract critical aspects for this developing ability. The extent to which the ability to *read nature* can be transferred between ecosystems is another aim of the study. The relevance of *reading nature* as a goal in science education is also studied by discussing the concept with experienced teachers and student teachers.

Data was collected mainly by interviews before and after instruction. The students were interviewed outdoors and they were basically asked to describe the ecosystem and explain why it looked the way it did. The main issues discussed in the interviews regarded the organisms and the non biological factors influencing the ecosystem, the ongoing cycles and processes in the ecosystem and finally the human influence on the ecosystem. Concept maps and video recorded field studies has supplemented the interviews in the analysis of student ability to *read nature*.

Prior to instruction all students found it difficult to *read nature*. Linking ecological theory to the authentic environment seems difficult to do. The school students followed teaching sequences aiming at developing their ability to read nature. Critical aspects for developing the ability to *read nature* had to do with developing an ecological language including ecological terminology as well as the naming of common organisms. An experience based ecological knowledge of a few common species was for many students a helpful link between taxonomy and systems ecology. The recognition of the morphological and behavioural characters of different functional groups together with the principles of the food pyramid model and the cycling of matter were three critical aspects guiding the reading of nature in a new ecosystem. Abstract processes such as photosynthesis and natural succession were difficult to grasp for most students and the field based instruction did not seem to support this learning. There was a strong support for *reading nature* as a goal in science education where the outdoor aspect of ecology was stressed and the implications for this has to do with supporting the future generation of teachers to study nature in the real context.

ACKNOWLEDGEMENTS

This first page of the thesis is really the last lines I write before closing a five year project which has been both a privilege and a struggle. Along this journey I have met with so many people who have supported me in many different ways. I would first of all like to thank all the students who I have had the pleasure to follow in their learning processes and during several long interviews in different types of weather. Thanks for sharing your ecological ideas with me. I would also like to thank Ingegerd, Sam and Elisabeth who have been supportive teachers for these students and very helpful in my work.

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Gärds Köpinge, on the vernal equinox, 2007

To Karin, Klara Malva & Julia Linnéa

TABLE OF CONTENTS

1. LIST OF PAPERS*

This thesis is based on the following papers, which are referred to in the text by their Roman numbers:

Paper I **Magntorn,O**., & Helldén,G. (2005) Student-Teachers' Ability to Read Nature: Reflections on their own learning in ecology. *International Journal of Science Education* 27 (10) 1229-1254.

Paper II **Magntorn,O**., & Helldén,G. (2007) Reading New Environments: Students' ability to generalise their understanding between different ecosystems. *International Journal of Science Education* 29 (1) 67-100.

Paper III **Magntorn,O**., & Helldén,G. (2007) Reading nature from a 'bottom-up' perspective. *Journal of Biological Education* 41 (2) 68-75.

Paper IV **Magntorn,O**., & Helldén,G. (2006) Reading Nature- experienced teachers' reflections on a teaching sequence in ecology: implications for future teacher training. *NorDiNa- Nordic Studies in Science Education* 5 67-81.

*According to agreement within the LISMA group and FontD the supervisor is regularly a co-author on the papers

2. PREFACE

As a young student in secondary school with a strong biology interest I was often disappointed with the subject of ecology being highly quantitative and densely packed with ecological definitions. It was far from connecting with my feelings and largely isolated from authentic experiences in nature. Later, in my university studies, I came to realise that you need both of these factors for appreciating ecology. Not only the fascination for the beauty and complexity of nature, but also for the scientific way of describing and analysing nature. The ways the relations and adaptations can be expressed in the language of science and studied with scientific methods is vital. I believe reading some of the work of Linnéus has inspired me. The books about his travels in Sweden, with his colourful descriptions of nature, based on his observations and his curiosity for natural history are fascinating to read. What is most inspiring from his texts is his curiosity for the relationship between the individuals and the whole ecosystem. He was really very good at observing the structures in nature and relating them to his prior experiences from earlier field studies. His saying *Maxima in minimis* reflects his fascination and wonder for the smallest things in nature. Despite being 300 years since he was born his descriptions of natural history are still remarkably relevant although his scientific assumptions are often far from contemporary ecological ideas. Indeed he was more of an observer than an experimenter.

Another source of inspiration for the observation but also for experimentation and interpretation of nature was geneticist and Nobel laureate Barbara McClintock whose approach is described in her book "a feeling for the organism" (Keller, 1983). In her work she really made the corn plants talk to her about their responses both to their inherited characters but also to environmental factors. *Reading nature* has to do with this fascination for, and understanding of, natural history in combination with scientific theories for the ongoing processes in nature. It has to do with studying real organisms and seeing them as parts of a larger system. My experience is that people of different ages that I have met, both as a teacher but also in out-of-school situations find it very difficult to *read nature* in the habitats in which they may have spent a large part of their lifetime. I see this ability as something of importance and as being something central to the scientific field of ecology but also as a part of our concern for nature and for sustainable development.

3. INTRODUCTION

3.1. Aims of the thesis

This is a thesis in science education with a specific focus on ecology education and ecological literacy. Seel (1999) defined science education as the science of the teaching profession, and the task of the discipline was defined by Andersson (2000) as creating, developing and maintaining the knowledge about science teaching under different conditions and with different content. As Helldén, Redfors & Lindahl (2005) write; science education has three important contact surfaces. The first surface is linked to disciplines such as "pedagogy and education". The second is facing towards practical teaching and the third is related to the content of the scientific subjects. I see the design of my thesis as contributing to the three facets where the main focus is on the content of the subject together with the ideas of how students learn to *read nature* and the role of the teacher in this process. I hope my contribution to science education can be both a clarification of my view of an important aspect of ecology education and also influence school activities in the line with Lijnse's view about the close relationship between research and teaching. He wrote "The primary aim of (research in) science education is content-specific didactical knowledge, based on developing and justifying exemplary science teaching practices" (Lijnse, 2000).

The backbone of this thesis consists of the four papers published in refereed international scientific journals. The main content of the articles has to do with students' and student teachers' developing ability to *read nature*. Two of the articles also have a metacognitive component and deal with important conditions for learning to *read nature* and for the relevance of this ability in a school context. To put these articles in a larger perspective I initially define the scientific content knowledge of *reading nature* in relation to the broader field of ecology. This is followed by a discussion of my educational approach where I basically regard: a) how students and student teachers develop their ecological understanding, and b) the relationship between conceptual understanding, ecological language and literacy. Then, after having demarcated the concept of *reading nature* in relation to ecology and ecology education I have also found it necessary to limit my analytical focus to a few higher order cognitive skills. These are: systems thinking, transfer of knowledge between different ecosystems, and the ability to discern and discuss relevant structures in nature. In the analysis I have used several different analytical tools to evaluate the data and to illustrate the findings in relation to the issues a) and b) above. Interviews have been the main source of information and the teaching sequences have been carefully designed in close cooperation with the teachers.

The thesis discusses the following issues:

a. What *reading nature* is
b. Why it is important to learn to *read nature*
c. How the ability to *read nature* can develop

The first two issues aim at describing the concept *reading nature* from a broad perspective involving both science and science education. It is also important to define the abilities and competencies involved and how do they vary between different age groups. The importance of this ability is discussed in relation to the curriculum, to teachers' views and to the larger field of ecological educational research. The main focus of this thesis is on how the ability develops.

3.2. Who should read this thesis and why?

The main target group for this thesis is the large community of researchers in science education. Ecology is an important but limited part of science, hence to help those researchers without deeper knowledge in ecology I have given a general description of the relevant ecology content in this context together with a description of the common educational challenges in this field. As I see it, my work contributes to the research in several ways. First of all the collection of data has taken place in the outdoor context which is not unusual but outdoor research with a focus on content knowledge is rare. Most outdoor educational research deals with students' attitudes, activities or interactions during field work. The learning outcome is rarely investigated in the field. Another reason for reading the thesis has to do with the different methods of analysing the data where I have tried several taxonomies and coding schemes in order to illustrate the developing complexity in students' explanations. I believe these tools to be useful to other fields of science education and to education in general. In my definition of *reading nature* I have decided that certain things are important. There are other parts of my understanding as an ecologist that does not have anything to do with *reading nature* but I argue in the thesis for the importance of the concept as a central part of science education.

As a biology teacher and as someone who meets people who you want support in their learning about the fascinating natural world surrounding us, I hope that what I have found may interest you. In the papers I have tried to describe the teaching design in sufficient detail that it may give you some ideas of how to improve your own instruction. The main contribution of the findings, for practitioners, as I see it, has to do with the empirical data on the influence of the outdoor context when teaching ecology and the influence of focusing on a few organisms in nature as a starting point for more abstract reasoning.

3.3. How should this thesis be read?

Depending on the reader's interest there are several separate parts in this thesis. For the main target group the theory about ecology and *reading nature* may be most interesting and important for anyone who is not an expert in ecology education. The section about theoretical framework and particularly the section on Human constructivism is expected to be familiar for the main target group. For scientists, however, this section may be relevant for the understanding of the thesis. If you are familiar with science education research, you may find the summary of the articles and main conclusions most interesting. If, on the other hand, your knowledge of the concepts and research procedures in science education is weak I hope the chapters about Theory and related research (chapter 4) may be helpful. In chapters 6 and 7, I discuss my research design with the advantages and drawbacks of the chosen methodology. I have also tried to put some information in tables and figures and perhaps you can get an overview of the thesis by studying these summaries.

The four papers are connected in the sense that they all deal with *reading nature* and the developing ability to do this. There is however a different focus in each of the articles. The first paper deals with student teachers and their views on their own learning and the important learning situations for developing the ability to *read nature*. In the second paper I follow a class of lower secondary students while they study a forest ecosystem, from a top-down design starting with the abstract processes in nature and gradually moving towards the concrete structures such as animals and plants. The main focus is on their ability to transfer the *reading* of the forest to another ecosystem - a pond. In the third paper I follow a primary class when they study an ecosystem, a river, from a bottom-up perspective. The instruction starts with the study of a single organism (a shrimp) and its ecology and gradually more and more abstract components of ecology are added. The fourth paper is based on a video, presenting the instruction and student activities from the third article. Experienced teachers discuss the possibilities and drawbacks of implementing this design for teaching in their everyday classrooms.

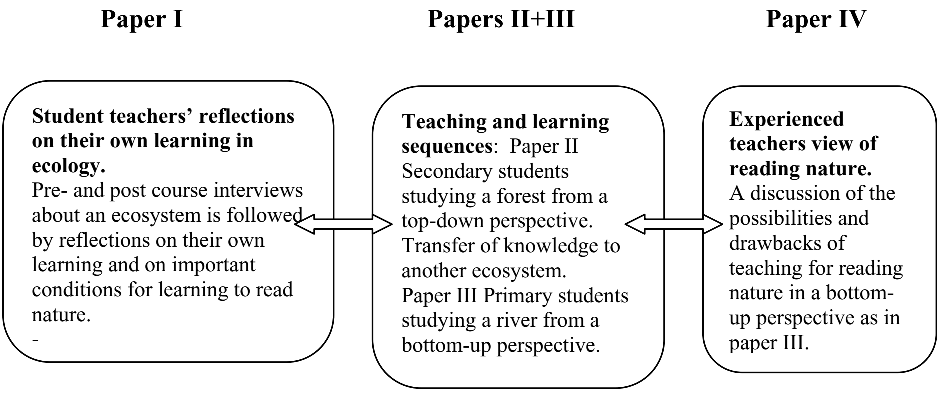

Figure 1. **This figure illustrates how the four articles are written as a sequence starting with defining *reading nature* and reflections on important learning situations. In papers II and III teaching sequences are designed and evaluated. In the fourth article experienced primary school teachers reflect on a video from one of the designed teaching sequences.**

So far I have given an overview of the content of this thesis with its different parts and its constituent papers. In the following section I will discuss why *reading nature* is an important aspect of being ecologically literate and how this research adds new knowledge to the field of science education. I will also argue for the relevance of this research by referring to the content of the national curriculum in biology.

4. BACKGROUND

4.1 Justification of the study in relation to previous research

Literature concerning students' explanations and understanding of ecology and in particular research with a systems focus suggests that students do not have a good grasp of the complexity of food webs, of energy flow or of the dynamics and structure of ecosystems (Adeniyi, 1985; Gallegos et al, 1994; Hogan & Fisherkeller, 1996; Leach, Driver, Scott & Wood-Robinson, 1996; Grotzer & Bell Basca, 2003). If we start with photosynthesis and respiration, the first is understood in many ways. A commonly held (Aristotelian) idea is that plants get their "food" from the soil. (Wood-Robinson, 1991; Carlsson 2002 and Helldén, 2004). Leach et al. (1996) showed that students have difficulties differentiating between energy and matter in ecosystems. Ideas of consumption of energy are commonly held and the transformation of matter is not commonly understood (Watson & Dillon, 1996, Hogan & Fisherkeller, 1996; Carlsson, 2002). The process of respiration, particularly in plants, is completely unknown to the majority of students (Leach et al. 1996; Helldén, 2004). This short review gives a hint of the focus of most ecology education research over the last decades, where students' difficulties in understanding the abstract processes in nature have been the main focus. Another aspect of ecology education which is focussed in my study is the knowledge of organisms and how they live in their environment. Often this is not common knowledge for students and research has shown that students in general know a limited number of organisms in their nearby nature and that they have great difficulties with the classification of animals and plants (Lock et al. 1995; Kattmann, 2001 and Bebbington, 2004). The knowledge of how invertebrates live and of their life cycles is yet another area where research has shown limited understanding among school students (e.g. Shepardson, 2002). In my research I am not primarily interested in how they understand the isolated phenomena but rather how their understanding of the visible objects in nature such as animals and plants is related to the abstract phenomena in the natural context. i.e. how they can use systems thinking in nature. By studying an ecosystem and building the examples and the theories around what one can see in this ecosystem I hope to reduce another problem which has been shown in ecology education, namely that the students loose interest since they are not familiar with the organisms or the examples given in ecological textbooks (Magro et al. 2001). Several studies have been conducted on students' understanding of ecology and their attitudes towards nature before and after a field-based teaching sequence (e.g. Bogner 1998; Nundy 1999; Orion & Hofstein, 1994). In my study I have also designed teaching sequences with a large part of the instruction taking place within the ecosystem to be *read*. As Slingsby and Barker (2003) claim the nature of scientific enquiry is to make contact between abstraction and reality and to start from observations of the "real world". What is different from the studies mentioned above and a natural consequence of my research focus is that most of my data collection has taken place outdoors.

4.2. *Reading Nature* a new concept.

Reading nature is my own concept and it was coined when I started to analyse students' ability to describe an ecosystem and to explain why it looked the way it did. I have previously come across the concept *reading the landscape* in a course in cultural geography. To me the concepts *reading nature* and *reading the landscape* stress the contextual knowledge saying that the reading has to take place outdoors. This is why I find *reading nature* a useful concept. It soon became obvious that this "literacy" was complex and consisted of many abilities. Since *reading nature* has no established definition or real recognition in everyday language, or in people's minds, the meaning of the concept must be clarified. Basically it has to do with discerning relevant and typical structures, such as plants and animals, within an ecosystem. Knowing the names and the ecology of the common and typical organisms is only one aspect, and needs to be supplemented with the understanding of their internal relationships together with their relation to the cycling of matter and the flow of energy in the ecosystem to be *read*. For a more detailed description of *reading nature* see section 4.8.

To start with, I find it helpful to separate, and briefly discuss the two parts which constitute the compound notion. I will start by describing the concept *nature* and its relation to ecology and ecosystems. This is followed by a section where I discuss *reading* and literacy.

4.3. A definition of Nature in this context

Nature is a wide term with different meanings according to who you ask. Andersson (1993) stressed the difficulties associated with the varied use of this term:

> *"for some people e.g. , in poetry and in New Age movement, nature is a living being with omnipotent qualities, e.g. the character of being a living totality with rationality. For others nature is more tied to everyday life; biologists consider nature as an ecosystem, industrialists look at it as a resource, the hunters experience its wildlife and the artists discover its forms"(p.104).*

As the subtitle of my thesis indicates, my view of nature in this context has to do with ecology and ecosystems and the context is outdoors. I see nature as the elements and processes in our environment that people do not consciously control or govern. Nature is not only restricted to the elements and processes in the environment but it is also an area which can be demarcated in the landscape such as a forest or a river.

4.4. Ecosystems as part of nature

Ecology is a large component of the biology curriculum and the ecosystem is a central concept in ecology. This was exemplified by Cherett(1989) who developed a list of the 50 most important ecological concepts by surveying the members of the British Ecological Society where ecosystems was ranked number one by the majority. Most biology teachers today would probably agree with Cherrett's list and consider ecosystems as a fundamental part of the biological course content. In my research the unit of interest is the ecosystem and I would like to elaborate a little on the concept, its history and its delineation. The notion ecology was first used by Haeckel in 1869. It comes from two Greek words *oikos* meaning home and *logos* meaning understanding. Definitions of ecology all, more or less, have the same meaning - it is the study of the interrelationships of the organisms and their environment" (Wallace, 1997, p. 481). System comes from the Greek root *systema* meaning 'what is holding together'. Systems can be defined as 'sets of elements standing in interrelations' (Bertallanffy 1975 p 55). So, nature in my concept *reading nature* has to do with ecology and the recognition and understanding of ecosystems. I will discuss the concept *reading nature* in section 4.8 but for readers without a specialisation in ecology I will start with positioning the concept in relation to the growth of ecosystems ecology as a scientific area of research.

Ecology in common thinking is ancient, people have always noticed that plants and animals seem to be shaped for the environment they live in. Fish were given fins to swim with and birds were given wings to fly with. These teleological arguments, that are often found when children discuss ecology (Helldén 1992), were common sense in the 18th century and Linnéus was fascinated with the clever arrangements in nature where each life form had a specific purpose in "nature's house keeping". His leading idea was that of "nature's balance" as "nature's foremost work" and "it must be ascribed to the animals obligingness that no single species out of thousands of plants will ever be totally exterminated" (Linnéus, 1760, in Politia Naturae). Linneus was a master at the time of animal and plant geography and he made detailed descriptions during his travels in Sweden. Despite his ideas of 'nature's balance' he was also interested in the natural changes of the flora and fauna over time in a specific location, what we now call ecological succession. He could describe in detail how a peat bog with its red mosses (Sphagnum) became more dense and dried out.. to finally .. become the most dazzling meadow. In the 19th century several expeditions were carried out in "terra incognita" to describe and study the natural history of the remote places. For example Von Humboldt's expeditions collected data within several scientific fields such as botany, zoology, physical geography and meteorology. The correlations between abiotic factors and the distribution of species around the world provided many new pieces of the giant jigsaw of life forms and conditions for life. Darwins' revolutionary ideas started a new phase in the studies of the connections in nature. Organisms were seen as not formed to fit into the existing world but rather they were formed by it through natural selection. The abiotic factors together with the biotic factors such as competition and selection influenced life forms and the evolution of species.

Over the 19th century, botanical geography combined to form the basis of biogeography. This science, which deals with habitats of species, seeks to explain the reasons for the presence of certain species in a given location. It was not until the 20th century that Ecology was established as a scientific field, and since then, it has had an explosive development. Worster writes that the early ecologist Clement, in the 1930's, saw an ecosystem as a super organism which in its climax phase contained a large number of organisms which were as dependent on the other organisms as the organs are in a body. The climax stage of an ecosystem was stabile, the organisms were highly specialised, species diversity high and nutrients were utilised very effectively. Succession was a natural process towards perfection. When he saw the effect of the cultivation of the prairies with sand erosion and depletion of the soil creating an ecological catastrophy, he talked of nature's revenge when humans disturbed the "natural balance" (Worster, 1994). It was in 1935 that Arthur Tansley, the British ecologist, coined the term ecosystem, the interactive system established between the biocoenosis (the group of living creatures), and their biotope, the environment in which they live. Ecology thus became the science of ecosystems. He criticised Clement's idea of a super organism - he claimed that ecosystems (plant societies) could not be classified. They were ephemeral states of nature and succession for instance never followed exactly the same pattern. Where Clement saw humans as intruders in ecosystems Tansley regarded human influence as a natural component in the ecosystems and claimed that the processes taking place in a natural ecosystem were basically the same as those in an anthropogenic ecosystem. Maybe their different contexts influenced thier views whereas Clement studied the prairies with very little direct impact from human activities; Tansley studied the highly cultivated English countryside. Tansley and Clement represent two different views of ecosystems. Tansley stressed single organisms and their activities whereas Clement stressed the system as an organic whole. Tansley is regarded as an autecologist who studied single organisms and their relation to their surroundings; how they survive and how are they related to the other organisms in the same habitat. Synecologists like Clements, on the other hand, study whole ecosystems, such as forests or lakes, and the turnover of minerals and the flow of energy. The in- and outflow of substances is their main interest and the organisms are only parts of a whole system.

In the 1950's Clement's synecological ideas about succession and systems were supported by the Odum brothers who developed an interest for the larger scale processes which contributed to the entire system in the natural world. They criticized the ecologists who "were satisfied with just describing nature's 'appearance' with its organisms and environmental conditions" and saw ecology as a field in need for a uniform theory for the ecosystem, presented in mathematical and statistical terms - a holistic, and not a reductionistic theory (Sandell et al. 2004). As we will see a large part of the ability to *read nature* has to do with this recognition of organisms and understanding of their conditions for life.

In Sweden the first professorship in ecology was established as late as 1968 when ecology was finally supported and financed by the state. Söderqvist (1986) wrote that "In the 70's the Odum brothers were very influential and the ecosystem was focused on with grandiose projects where whole pine forests were fed into computers. For millions of kronor masses of ecologists measured, weighed and counted needles. They collected and analysed rain water and soil water in small funnels and they collected earth worms and springtails among many other things. Everything was fed into the computers and voilà- nature could be unravelled!" By describing the large ecosystems on earth Odum (1966) wanted to encourage a stronger interest in the mutual relations between humans and the environment. The link between this so-called modern ecology and a growing environmental movement was strong. The cybernetic ideas of ecosystems as predictable and arriving at an equilibrium through feed-back mechanisms was criticized by many population ecologists. One of them was Robert May who in the 1970's studied population dynamics among invertebrates with short lifecycles. He found that sometimes the predicted mathematical development did not appear and something more like chaos appeared even under controlled conditions. In May's world complex ecosystems appear unpredictable and chaotic. His conclusion was that "even if nature was one hundred percent predictable" still the resultant population sizes sometimes were "impossible to tell from chaos". It is worth noticing though, that he was not denying biological population laws but his point was that these laws could result in processes in nature which could not be separated from processes based on chance (Uddenberg, 2004).

So, when looking at the ontological development of the concept, ecosystem, the transition from holistic views of an ecosystem as a sort of organism via cybernetic ideas of feed-back regulations and equilibrium, to a dynamic or even a chaotic view has not fully reached the school biology curriculum in Sweden and in other countries (e.g. Westra 2005, González del Solar & Marone, 2001). But why is it that the ideas of nature being self organising and stable have been so long lived outside the universities? Partly, it is due to the fact that the organisms inhabiting an ecosystem are parts of a complex network where one life form is dependent on the other. Even if the ecosystems cannot be regarded as organisms they are still organised and often the ecosystems are relatively stable over time. An alpine meadow or a sandy beach , after all, appears to be staying the same from year to year. In the mass media and public debate regarding ecology and nature conservation the moral tone used refers to "natures balance" and the "laws of nature". The borderline between science and a normative outlook on life becomes blurred (Uddenberg 2004). *Reading nature* has to do with the study of ecosystems with its organisms and their complex relations and a goal in education for *reading nature* has to do with enthusing the next generation to act on behalf of the natural world. When it comes to issues such as whether one ecosystem or one species is more valuable than another it is not within the scope of science education but rather related to feelings and view of nature.

Where does ecology research stand today? Well, according to Sandell et al. (2005) population ecology is a large field with its focus on how the size of a population is influenced by factors both within the population but also with the level of interactions with populations of other species. The key words have to do with competition, predator-prey relations, niches and carrying capacity. The other great field is systems ecology which deals with how species interact with the abiotic world and how this results in an energy flow through plants and animals. A cycle of matter from the abiotic environment through the bodies of living organisms and finally back to the abiotic environment. The key words have to do with producers and consumers, food chains, food webs and trophic levels, biomass and food pyramids.

In a recent study Nobis & Wohlgemut (2004) studied how ecology had progressed over the last 25 years based on a word analysis in the titles of the articles in five core ecological journals. Ecological research has been repeatedly criticized for its lack of progress. Their findings are that most articles were related to the following key words: processes, landscape ecology, biodiversity, ecosystem research, modelling and food-web/predator-prey interactions. What is most interesting here in relation to *reading nature* has to do with the growing field of landscape ecology and biodiversity which is a discipline where taxonomy and ecology are combined. In general the methods in ecology have been increasingly sophisticated and ecologists need to associate with experts from other fields such as gene technologists or radio physicists in order to carry out their studies. Large groups of scientists from different fields have also cooperated, such as systems ecologists involving several different aspects of social science such as environmental psychology and environmental history in order to for example estimate the price tag for certain ecological services such as pollination or positive nature experiences (Sarukhan &Whyte 2005). Within biology the cooperation between ecologists and evolutionary biologists, has been very successful in determining the success of certain species. Another positive integration has been between ecologists and ethologists in the behavioural ecology. A long list can be made but the point is that ecology as a research field has developed dramatically over the last decades but still the knowledge of the individual organisms and their ecology is central in most of ecological research today. In *reading nature* this is also true and the nature to be read is the ecosystem. In the next section I will discuss literacy in relation to reading nature and how it is an important part of ecological literacy.

4.5. The relationship between scientific literacy and *reading nature*

Literacy is a term widely used in Anglo-American literature, having a meaning closely related to the Swedish expression "allmänbildning". A person developing literacy goes from the lowest form based on the ability to read and write to the highest form of literacy, the evaluative or analytical stage, in which the reader is expected to analyse and critique what they read and draw inferences on (Kintgen, 1988). Most discussions of literacy use the term as a goal, that one either achieves or does not, that is, a person is either literate or not. As I see it, along with Wellington & Osborne (2001), it is more appropriate to recognise that every person is somewhere along a continuum of literacy from being totally illiterate, and depending on others, to being an expert and independent on others. In the following section I have tried to describe *reading nature* in relation to the superordinate concepts of scientific literacy and ecological literacy where their mutual relations are important to illustrate (see figure 2).

4.6 Scientific literacy

Although the concept of scientific literacy was developed in the 1950's, it remains a universal and timeless goal for science education. In an ideal world, an individual's progress towards scientific literacy continues throughout life. There are several definitions of the concept and the OECD/PISA (2003) defines it as: "Scientific literacy is the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" . The American Association for the Advancement of Science document *'Science for All Americans'* (AAAS, 1990) describes a scientifically literate person as one who is aware that science and technology are human enterprises with strengths and limitations, understands key concepts and principles of science, is familiar with the natural world and recognizes both its diversity and unity, and applies scientific knowledge and skills for individual and social purposes. It is worth emphasising that both scientific knowledge and the processes by which this knowledge is developed are essential for scientific literacy and that they, bound together, define the concept.

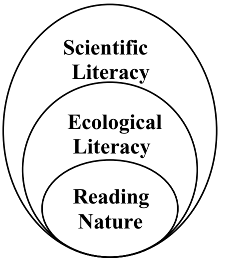

Figure 2 illustrates how the three concepts are related.

As I see it, this is a broad definition involving the whole field of science and it relates the human relationships to the environment.

Included in the many different definitions of scientific literacy (e.g. Laugksch, 2000, Graeber & Bolte 1997) are notions of levels of scientific literacy. Bybee (1997) proposed four levels. The two lowest levels are 'nominal scientific literacy' and 'functional scientific literacy'. The first consist of knowledge of names and terms, and the second of the knowledge of using scientific vocabulary in limited contexts. Bybee's third level is what is evaluated in most international as well as national tests in science namely ‘conceptual and procedural scientific literacy’ The highest level identified by Bybee is ‘multidimensional scientific literacy’. It includes understanding the history of science and its role in culture, which we see as an important part in the Swedish science curriculum today (see section 4.11.). All of these levels are important for my definition of *reading nature* though we have confined it to an ecological context.

4.7. Ecological literacy

In the literature about ecological literacy (e.g. Bateson, 1992; Östman et al. 2005; Orr, 1992) there is often no boundary between environmental literacy and ecological literacy and they both have strong links to environmental issues and sustainable development. This is obvious in the quote from Capra (1999) who points out the importance of ecological literacy as a goal in education:

"The great challenge of our time is to build and nurture sustainable communities – communities that are designed in such a way that their ways of life, businesses, economies, physical structures, and technologies do not interfere with nature's inherent ability to sustain life. The first step in this endeavour is to understand the principles of organization that ecosystems have developed to sustain the web of life. This understanding is what we call ecological literacy. Teaching this ecological knowledge – which may be called principles of ecology', 'principles of sustainability,' 'principles of community,' or even the 'basic facts of life' – will be the most important role of education in the next century. " (p.134)

According to Orr (1992) ecological literacy primarily constitutes ”knowing, caring and practical competence”. Orr further implies that ecological literacy encompasses an understanding of “*how people and societies relate to each other and to natural systems, and how they might do so sustainably*”. In other words, knowing how the world works and the dynamics of the environmental crisis and thus knowing how to preserve and maintain the environment. Ecological literacy is ideally about developing a rich knowledge base and multifaceted beliefs and/or philosophies about the environment which lead to sustainable development.

In my view, ecological literacy, as defined above, has a focus on an attitude and philosophy for sustainable living more than a focus on the scientific content knowledge of ecology. The latter is more connected to my focus. I see *reading nature* as an aspect of ecological literacy where the ability to be habituated to nature and to observe changes in nature due to direct or indirect influences from human activities are important. The attitude towards sustainable living is assumed to be an effect of the ability to *read nature* rather than the aim itself.

The concept ecological literacy does not say anything about the context in which this literacy is valid. It is not linked to a specific ecosystem, as *reading nature* is, but rather has a global focus. For me the context is highly important for the design of the study and the demarcation of the concept. My view is supported by Magro et al. (2001) who point out that: “*The analytical modes of teaching we often use, especially in science courses, abstract problems from the context in the perceived interest of clarity and simplicity. But this clarity is deceptive, because, devoid of context the ideas do not always encourage meaningful learning for the students”(p. 3.)*

From the broad perspective of scientific literacy and ecological literacy I will now narrow the scope down to what encompasses my definition of *reading nature*.

4.8. *Reading nature*

My unit of interest is the ecosystem and I will start by structuring the content knowledge involved which relates to aspects of ecosystem understanding from a theoretical perspective. I will start from the organisms and continue to their autecology followed by the systemic view of the whole ecosystem. This is what Magro et al. (2001) call a bottom-up description of the ecosystem. Starting with the organisms and the question of who they are and what they are doing here is the type of question Linnéus and his fellow natural historians or protoecologists asked themselves when they studied nature in order to describe the ecosystem. Synecology is more modern and involves models of relationships between biotic and abiotic factors in the ecosystem of which Linnéus knew little.

In the text below I will describe the concepts taxonomy, autecology and synecology since they are important and constitute the content knowledge which will be discussed throughout the thesis. Following from the description of content knowledge I will also describe how reading nature relates to the field of ecology and argue why I see reading nature as an important competence. The description starts by defining the three levels taxonomy, autecology and synecology.

4.8.1. Taxonomy

This is the science of classification of organisms which involves not only the names but also the process of naming and the science behind the classification. In this thesis I refer to taxonomy as the naming and ability to identify organisms from relevant field guides or other sources available for students. Having proper names for the typical species such as trees and herbs in a mixed deciduous forest is important for characterising the ecosystem. One important reason for having proper names for the organisms is mentioned already by Linnéus when he wrote '*Nomina nescis perit et cognita rerum*' ['If we do not know the names the knowledge of the things themselves is worthless]. (Linnéus, 1737). You have to be able to communicate about the organisms in the ecosystem. Taxonomy is a discipline in its own right but in the school context it has to do with naming, and refers to ecology in the curriculum (see section 4.11) I see it as a prerequisite for *reading nature*. It involves the discernment of a limited number of species in an ecosystem. It has to do with the experience of looking for and of finding the organisms in the ecosystem and to correctly name them.

4.8.2. Autecology

This is the name given to ecological studies which concentrate on one species. The naming of the common plants and animals in an ecosystem has to be coupled with the relevant knowledge of why they are common in this ecosystem. The ability of an animal to avoid its predators, catch its prey, withstand disease and so on, will depend on the relationships it has with the organisms around it. Its life will also be affected by the weather, time of the year, the quality of the nesting and sleeping sites (Chapman & Reiss, 2003). The autecological focus in *reading nature* is related to the functional aspects of the organisms in the ecosystem to be read. By relating the morphology and the behaviour of an organism such as a butterfly larvae to its feeding it is possible to assume that it is a herbivore. Other autecological aspects have to do with adaptations to the environment such as the body shape of running water invertebrates in relation to the speed of water. The distribution and abundance of species in the ecosystem is also an important autecological aspect. Some organisms are very common and others are rare. In a stream there are more mayfly larvae in spring than in summer which has to do with life cycles which is another important aspect of autecology- the distribution of species over the year. By studying a few common organisms in greater detail through observation and experimentation a discussion about the interactions within the ecosystem is natural.

4.8.3. Synecology

This is when all the species living together are studied as a community and together with environmental factors they are studied as an integrated unit (Chapman & Reiss, 2003). I have divided this definition of synecology into two parts. The first deals with how the organisms are related to the other organisms where models of food chains and food webs are examples. The second which I have called the systems ecology is including the synecology but it also involves the abiotic factors such as cycling of matter and flow of energy. In a bottom-up perspective this naturally follows from the study of taxonomy and autecology and aims at describing the whole ecosystem. As I write in the description of the modern ecology and systems ecology (section 4.4.), this field involves making conclusions on a systems level based on large amounts of data. In a school context with young students, I see it as necessary to concentrate on the most important aspects of the ecosystem.

The ongoing changes in the structure and the species composition of a community i.e. succession, is difficult but important to recognise. This is a part of synecology which relates strongly to environmental issues, nature conservation and biodiversity. The goal is to make the students aware of the anthropogenic influence both directly and indirectly that affects our ecosystems. It is important to recognise how the landscape naturally changes over time but also to recognise human influence on the natural succession.

4.9. *Reading nature* in relation to other parts of ecology education research

The content of biology as a school subject is naturally based on a long tradition of biological research. There is a necessary selection of content and adaptation of complex issues to the current school level. If we look at a subject like ecology there is a discrepancy between the frontline of ecological research and the content presented in the schoolbooks. The reason for this has, of course, to do with the complexity of applied research which demands basic ecological understanding to grasp. The problem with school books as I see it is that often they include an array of ecological terms and give the impression that the terms are the ecology content. This is supported by other researchers (e.g. Delpech, 2002; Hale 1994). My concept of *reading nature* does not focus on ecological terminology so much and a large part of it has to do with natural history. The organisms and their autecology is the starting point and the context is the ecosystem. The content of *reading nature* is illustrated in the concept map in figure 3.

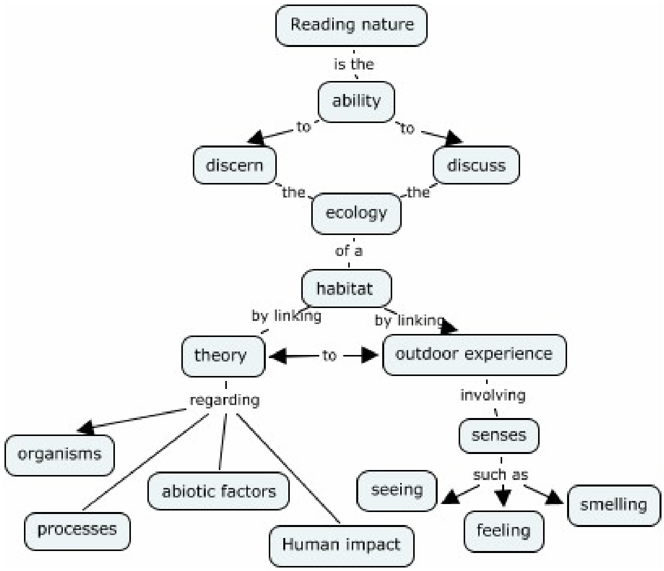

Figure 3. Concept map illustrating the concept *reading nature*.

In the concept map the ability is described both as discernment of objects in nature which can be related to theory but also the ability to discuss the ecology such as what organisms there are and why they are there. Theory has to be linked to field experiences where different senses are involved. The content is the relationship between biotic and abiotic factors and the most important processes involved. The awareness of human influence both directly and indirectly in the ecosystem is also part of *reading nature*.

In section 4.8. I describe the specific content knowledge involved in *reading nature* in relation to ecological and scientific literacy. I would now like to narrow this down to the more specific competencies involved in *reading nature*. In the list below I have tried to pinpoint the competencies. The list is inspired from my own experience as a teacher in ecology at school and university level. It is also inspired by the Swedish National curriculum (Skolverket, 2007) which deals with four aspects of content knowledge: *facts*, *conceptual understanding*, *familiarity* and *proficiency*. In Swedish this is often referred to as the four F:s (Fakta, Förståelse, Färdighet and Förtrogenhet) and I would like to add a fifth aspect which I regard as a consequence of meaningful learning and that is: *Fascination*.

In the list of competencies and proficiencies involved in reading nature (figure 4) I have summarised the main content in the ability to read nature. The list is based on previous research in the field together with my experience as a teacher and an ecologist. The names linked to each competence represent examples of researcher dealing with this field and they are derived from relevant research literature.

- **Content knowledge (facts, conceptual understanding, familiarity with):**

-proper names for structures in nature such as naming of plants and animals. *(e.g. Bebbington, 2005)*

-proper ideas about the autecology of organisms *(e.g. Shepardson, 2002)*

-linking the organisms and their autecology to other organisms in the ecosystem *(e.g. Leach et al, 1996)*

-linking the populations of organisms to the whole ecosystem- systems thinking (e.g *Assaraf & Orion 2005*).

-relating the biotic and abiotic components to the cycling of matter and the flow of energy in the ecosystem. (*e.g. Assaraf & Orion, 2005***)**

- relating human influence to the structure and the function of the ecosystem. *(e.g. Orr, 1992)*

- **Proficiencies:**

-Discerning relevant structures in nature- having the right eyes. *(e.g. Marton, 2006)*

- Being able to discuss ecology by using the proper names and relevant expressions when *Reading nature* – having the right language *(e.g. Lemke, 1990).*

- Knowing how to act in order to find out relevant things about nature e.g. where to look, how to collect relevant material and examine it i.e. collecting and examining animals in running water. *(e.g. Slingsby & Barker, 1998)*

Figure 4. List of competencies involved in *reading nature* with relevant references included.

4.10. Knowledge emphases- why is it important to learn to *read nature*?

The content knowledge included in the school subjects is put under a constant scrutiny of whether they are relevant or not. If they are to be part of the curriculum they have to be acknowledged as important for one reason or another. So, why is reading nature supposed to be an important part of biology education? Questions of this kind need to be met with objective rather than subjective arguments relating to the usefulness of the competence. The ability to *read nature* holds many different competencies. Rosenthal and Bybee (1987) stressed a major distinction in biology education which can be found in different school biology courses. They expressed it in the following way:

" A major theme throughout the history of biology education has been the continuing debates about its primary goal: whether it should be a science of life and emphasize knowledge or whether it should be a science of living and emphasize the personal needs of students and the social needs of society." (p. 123).

How can a school science subject have two such different meanings and are they compatible or conflicting? Roberts (1988) who analysed the underlying meaning of curriculum content which he called "curriculum emphases " stated that each of the emphases provides an answer to the student question "Why am I learning this stuff?" (Roberts & Östman, 1998). Roberts would probably say that the curriculum emphases of the first could be "*Correct explanations*" or "*Structure of science*" while the other could be "*Everyday applications"*, "*Self as Explainer*" or "*Science, Technology and Decisions*".
Robert (1988) presented seven "curriculum emphases in science education. The emphases are:

Everyday coping- to socialize the student to grasp science as a way to make sense of objects and events of everyday importance.

Structure of science- understand how science functions as an intellectual enterprise and of the growth and appraisal of knowledge.

Self as Explainer – how the student develops ownership in the process of explaining by understanding what the process is all about.

Scientific skill development- Using the right processes in the right situations produces reliable knowledge.

Solid foundation – this has to do with understanding a certain subject now, so that one can build on this for understanding what comes up next in the science course.

Correct explanations- is to question whether science presents the correct explanations or not.

Science, Technology and Decisions – To involve other aspects apart from science in discussions about future large scale issues such as environmental problems. (This is what we today refer to as Education for Sustainable development (ESD))

If we now turn to *reading nature* as a part of science the most important emphasis as I see it has to do with the *everyday coping emphasis* where it can be regarded as common knowledge to be able to identify common plants and animals and recognise different edible plants or places suitable for growing certain plants. Another emphasis is *scientific skill development* where the learner for example develops a battery of methods and ideas of how to conduct surveys or field work or maybe how to examine organisms correctly. A third emphasis is *solid foundation*, where the knowledge of common organisms and their adaptations to the environment can be a prerequisite for a continued discussion about a whole ecosystem functioning. *Education for sustainable development*- The recognititon of the common ecosystems with their natural inhabitants and the cycles of matter and flow of energy is an important reference which can help the reader of nature to recognise when human impact alters the ecosystem.

Apart from Roberts' curriculum emphases there are other emphases linked to *reading nature* which I would like to stress:

- Appreciation and fascination for nature. A large cross age study of the Swedish peoples' attitude towards nature showed a very strong appreciation for being out in nature. (Uddenberg, 1999).

- Literacy and the language of ecology. Learning science means learning to talk science (Lemke, 1990). Each scientific discipline has its own semantic and learning to express relationships between its concepts and is of key importance in mastering a discipline (Lemke 1990, Mortimer & Scott, 2003; Sutton, 1995). The literature on the semantics of science is extensive but the analyses are usually based on the researcher's view and not, as in my case, the students' own views. One way of describing the relationship between an ecological language and a natural language such as English is in terms of the linguistic notion of *register.* Linguist, Michael Halliday (1978 p. 65), specifies this notion as "a set of meanings that is appropriate to a particular function of a language, together with the words and structures which express these meanings". The expression of ecological ideas and meanings, is when an ecological register will develop. Handling the registers of the scientific language is an important component in the ability to *read nature*.

- Outdoor experience. Knowing how to act and how to survey and study nature in a correct and effective way has to be learned by outdoor activities and it is a form of tacit knowledge.

- Discernment. Being able to see things in nature and to discern the differences and similarities between objects in nature. This is again a tacit knowledge important in the ability to *read nature*.

Now, if we turn to the curriculum for compulsory school i.e. the students in primary and lower secondary school. I have chosen to present the parts about ecology and biodiversity in full text. I found it important to present the text as a whole since it is densely packed with goals relevant for *reading nature* which I would like to relate back to further on in the thesis.

4.11. *Reading nature* in relation to the Swedish Curriculum

The text below is from the Biology curriculum in the Swedish compulsory school year 1 through to year 9 (age 7- 15).

> **Aim of the subject and its role in education**
> The subject of Biology aims at describing and explaining nature and living organisms from a scientific perspective. At the same time the education should consolidate the fascination and joy of discovery and Man's wonder and curiosity in all that is living. The subject also aims at making knowledge and experiences usable to promote concern and respect for nature and one's fellow men.
>
> **Goals to aim for**
> The school in its teaching of biology should aim to ensure that pupils
> *concerning nature and Man*
> – develop their knowledge of different forms and conditions of life,
> – develop their knowledge of the interaction between organisms and their environment,
> *concerning scientific activity*
> – develop their knowledge of the importance of biology for Man's way of representing, using and experiencing nature,
> – develop a knowledge of different working methods in biology, such as field observations and laboratory work, as well as a knowledge of how these interact with theoretical models,
> *concerning use of knowledge*
> – develop their concern and responsibility when using nature,
>
> **Structure and nature of the subject**
> Four central dimensions characterise the approach of the subject of biology: ecosystem, biological diversity, cells and the human being. In all these four dimensions, a knowledge of biology is useful in connection with existential issues, which concern both the individual and society as a whole.
> *Ecosystems*
> The subject of Biology introduces the concept of ecology and provides a view of the interaction between organisms and their surroundings. The subject covers, amongst other things, a knowledge of subsystems involving producers, consumers, recycling and raw materials, as well as a knowledge of dynamic processes in the ecosystem, such as the flow of energy through the system and the recycling of substances. Studies of individual organisms, populations and their societies provide the foundation for this. The subject

also covers the aesthetic and ethical aspects of experiences arising from contact with nature. Questions on the preservation of natural species are dealt with by the tools of science as well as the inspiration and ideas originating from other human activities, such as outdoor life, art and literature.
Biological diversity
The subject presents the way in which biological sciences organise and systematise the diversity of nature. Fundamental starting points are theories about the ecosystem and evolution, as well as knowledge of different species and knowledge of the living conditions and relationships between plants and animals.
Everyday experience of diversity in nature is often ethical or aesthetic and expressed, for example, in different forms of environmental involvement. One of the most important contributions biology can make to studying Man's relationship with nature is thus to show the diversity of forms of life from scientific, aesthetic and ethical perspectives.

Goals that pupils should have attained by the end of the fifth year in school
Pupils should
concerning nature and Man
– recognise and be able to name common plants, animals and other organisms in the local environment, as well as be familiar with their environmental requirements,
– be able to give examples of the life cycle of some plants and animals and their different growth processes,
– have a familiarity with narratives about nature which are to be found in different cultures,
concerning scientific activity
– have an insight into experimental work, as well as recurring field observations in their immediate environment,
– be familiar with some examples where discoveries in biology have influenced our culture and view of the world,
concerning use of knowledge
– be able to take part in discussions on the preservation of different types of nature and diversity of species,

Goals that pupils should have attained by the end of the ninth year in school
Pupils should
concerning nature and Man
– have a familiarity with some of the world's ecosystems and how interrelationships between organisms can be described in ecological terms,
– have an insight into photosynthesis and combustion, as well as the importance of water for life on earth,
– be able to give examples of recycling and accumulation in an ecosystem,
– be familiar with the basic features of the development of life, as well as the conditions for and importance of biological diversity,
concerning scientific activity
– be able to make observations in the field and carry out experiments, as well as have an insight into how they can be designed,
– be able to carry out and interpret simple measurements of environmental factors,
concerning use of knowledge
– be able to use not only scientific, but also aesthetic and ethical arguments in issues concerning the preservation of different types of nature and diversity of species,

(www.skolverket.se 20070311)

Irrespective of how you read the national curriculum you find support for much of the content knowledge in *reading nature*. The ecosystem is central and the organisms in the local environment together with biodiversity and interrelationships between organisms are highlighted. Recycling, photosynthesis and combustion together with the importance of water in the system are examples of content knowledge stressed in the curriculum and central for *reading nature*. Fieldwork and observation is also mentioned as well as developing concern and responsibility for nature. What I see as problematic and where my thesis hopefully can be a contribution is its lack of structure. The curriculum leaves the teacher with very little advice of how best to reach these goals. I do not support a curriculum with fixed guidelines of how to perform the instruction but I believe the teachers need some guiding along their route to meet the curriculum demands. Hopefully this thesis can be a support in the planning and realization of future ecology education. A key concept both in the national curriculum as well as according to the British Ecological Society (as we saw in chapter 3.4.4) is the concept *ecosystem*. In the following section I will discuss this concept in a little more depth and in an educational perspective.

4.12. The ecosystem as a model in relation to *reading nature*

The definitions of ecosystem depend on the perception of nature and this is reflected in the technical terms. It is problematic to define an ecosystem as an area (biotope) if the connections between the organisms are emphasized, which may go beyond the borders of the area (Knight et al 2005). Also the separation of the community from the abiotic components can be criticized (eg Begon et al 1997). Such critique corresponds to that of Tansley (1935). The physical features of the habitat plus the climatic influences determine which species form the basic structure of the community. The ecosystem consists of the community of organisms plus the associated physical environment. So, where does an ecosystem start and where does it end? One can argue that the term is superfluous, because a community can never be separated from the abiotic components of the environment which have no such borders (Begon et al. 1997). Jelemenska (2006) writes that the connection between seeing an ecosystem as a mental construct or on the other hand as a fact of nature has to be considered. Reification is common where Odum (1990) uses the metaphor of "china boxes" to demonstrate a spatial container conception with boundaries and isolation of ecosystems from each other. In this study I see it as useful to try to demarcate the ecosystem. In an educational context it is important to define the physical area for the investigation. Often an ecosystem is well defined such as a pond or a river but it is important to discuss its influence by the surroundings. Students have great difficulty in accepting that an ecosystem in a glass container can be self-sufficient. This challenges their worldview and can be the start of a discussion about a systems view with its emergent phenomena where the ecosystem is influenced by factors on both a small and a large scale (Andersson, 2000).

I see ecosystems as a purposeful construct for research and education where the boundaries are the critical part of the model. The boundaries, that we can perceive or imagine, are taken as self evident criteria for the definition of the concept ecosystem. Jelemenska (ibid.) writes that "reification is an equalization between reality and perception". This means recognition that concepts are mentally constructed units and cognition must be distinguished from reality. Again we see that ecosystems are mental constructs and not real units of nature. We need, as Tansley pointed out, a model that we can agree on and that we also understand that it is a human construct.

I would like to finish this discussion about my view of ecosystems as a human construct being useful for education by referring to Wallin (2004) in her discussion about epistemology and ontology in relation to learning about the theory of evolution. She used Popper's (1972) three worlds and related this to her ontological view. Popper distinguishes three separate worlds:

First world:	The material world – *Nature*
Second world:	The subjective or mental world, constituted from our conscious experiences – *our understanding of nature*.
Third world:	The objective ideal world, constituting the logical content in books, libraries, computers etc.-*the ecosystem with its borders*

Regarding the third world, it is entirely a human construct and the ideas may not be true but they can be improved. Knowledge is therefore, according to Popper, always possible to work with and improve. The knowledge I work with is therefore related to *world three* and the knowing relates to *world two*. The phenomenon described and explained in ecology which is described in world three exists in *world one* and can be intelligibly understood in *world two*.

Teaching for the synecological level of *reading nature* has to do with linking theories of systems ecology with the real world experiences from field work in the ecosystem. Therefore ideas of systems thinking (world three) has to be introduced to the students.

4.13. Systems thinking as a part of *reading nature*

The necessity of adopting a holistic understanding has been advocated by, for instance, Keiny (1991) and Carlsson (1999) Keiny argues that, in order to be more fully understood, ecological issues and environmental problems in general, must be tackled in an open, multidisciplinary context, rather than a reductionistic and mechanistic one.

> *Systems approach is based upon a complete change of world view, as well as of paradigm. Instead of the traditional reductionistic, mechanical view which assumes that complex phenomena can be understood by reducing them to their constituent parts, system-approach views the world in systems of relationships and integration. […] Dissection of systems into isolated parts destroys their system properties. (Keiny 1991: pp 172-173).*

A methodology of a "systems approach" is believed to provide a basis for generating new questions and new ways of thinking (Keiny 1991). Ecology as a science often focuses on separate parts of an ecosystem and it is not until it is related to environmental topics that the holistic view is in focus. Ecology education in schools has, as mentioned earlier, the ecosystem as a key concept. This goes all the way from primary school up to upper secondary school. In science education research, as mentioned earlier (in 4.1) the studies on students learning and understanding of systemic features in ecosystems are rare (e.g. Assaraf & Orion 2005, Carlsson 2002).

The importance of a systems view in biology and the problems with the reductionist view is supported by Mayr (2004) in his book "What makes biology unique". He gives examples where reductionism is not going to lead to better understanding of the biological phenomena: "*What counts in the study of a complex system is its organization. Descending to a lower level of analysis often decreases the explanatory power of the preceding analysis. No one would be able to infer the structure and function of a kidney even if given a complete catalogue of all the molecules of which it is composed […] Actually in the course of downward analysis* *invariably a level is reached sooner or later where the whole meaning of the system is destroyed when the analysis is carried downward any further."*

So, what is a system? Assaraf & Orion (2005) presented it as: 'A system is an entity that maintains its existence and function as a whole through the interaction of its parts. However, this group of interacting, interrelated or independent parts that form a complex and unified whole must have a specific purpose, and all the parts must be present for this purpose to be carried out. Thus the system attempts to maintain its stability through feedback. The interrelationships among the variables are connected by a cause and effect feedback loop and consequently the status of one or more variables, affect the status of the other variables'.

In her thesis "Ecological Understanding" Britta Carlsson (1999) wrote about three fundamental system insights for understanding ecology:

- Photosynthesis is the foundation for all life on earth.
- All matter is involved in cycling processes of various lengths.
- Transformed sunlight is the basis for organisms' energy supply.

I agree with Carlsson about the importance of discerning these system insights for understanding ecology, but my point is that there is more to ecology education than teaching these fundamental systems insights. In her study the natural ecosystem is not included.

In my study, on the other hand, systems understanding is related directly to the objects in nature. Biological systems, like ecosystems, can be described as complex adaptive systems. Their complexity is due to the various structures and processes at each level of biological organisation (individual, population, community and ecosystem) as well as to the mutual influence of those structures and processes. In order to productively use modern ecological theory in a concrete ecosystem , one first has to establish a match between the ecosystem and theory. In a broad sense this process can be referred to as modelling, thus stressing the process of redescribing and reducing the concrete ecosystem (Westra, Boersma, Savelsbergh & Waarlo, 2006). This studying of the dynamics of a system remind us of Odum and the systems ecology in the 1970's, which involved numerous parameters and which demanded experts from different sciences and mathematical modelling far beyond what is relevant for school ecology. The systems thinking presented in this thesis relates to the understanding of already constructed models of systems and the challenging of these models. It deals with separation of the system from the environment and identifies the relevant elements of the system, its structures and dynamics. To avoid the risk of the reductionism mentioned by Mayr (2004) the visible organisms are central in systems thinking for reading nature.

4.14. Conclusion

Reading nature has to do with discerning and describing the ecosystem. The context is outdoors and the link between the organisms and the abiotic factors is important. In the research in ecology education there is a strong concern about the lack of field work in schools and consequently a concern about students' lack of ability to recognise organisms in nature. This is despite the emphasis on naming of common organisms in the curriculum where it also says that students should know about the organism's, their demands for life and about common ecosystems. I find that much of ecology education research has dealt with specific relationships or phenomena and rarely with the larger scale such as ecosystems. I also find that most of this research has taken place indoors and far from authentic ecosystems or objects of study. I therefore find my concept *reading nature* to be a relevant goal in science education and I find my research which is field based as a relevant contribution to the field of science education.

5. RESEARCH QUESTIONS

In the beginning of the thesis I stated three main issues to be discussed. Those were a) what I mean by the notion *reading nature*, b) why it is important to learn to *read nature* and c) how the ability to *read nature* can develop. In the thesis so far I have discussed two (a and b) of those issues and I will now turn to the third and the most important which is empirical and deals with how students develop their ability to *read nature*.

As I have described it in the literature review there are several difficulties involved in ecology education in schools today. This has to do with understanding the abstract processes such as photosynthesis and combustion. It also has to do with systems thinking and seeing the parts and the whole. The curriculum stresses the importance of knowing the common plants and animals in the nearby surroundings of the schools. There is also a goal saying that the students should know the most common ecosystems and to show the diversity of life forms from scientific, aesthetic and ethical perspective.

In the curriculum I see a focus on the organisms the ecosystem and the biodiversity. Implicit is also the idea of learning this through direct contact with nature. Examples of this are the following quotes: "Studies of individual organisms, populations and their societies provide the foundation" or "The subject also covers the aesthetic and ethical aspects of experiences arising from contact with nature. These are arguments for outdoor instruction but not stressing the field work enough as a method and my experience is that fieldwork are rare events in the compulsory school today.

5.1. The general research questions guiding my design of the study

The literature review on ecological education reveals problems with students' understanding of the content knowledge mentioned in the sections above. The difficulties of progression in understanding ecological concepts are well documented particularly as a result of cross age studies (Webb & Bolt, 1990, Driver et al. 1994, Leach et al. 1996 a, 1996 b.) but also as longitudinal studies (Helldén 1992, 1995, 1999, 2004, Ekborg 2002) The difficulties students have with biodiversity and classification have also been described as a decline in general knowledge about common organisms (e.g. Bebbington, 2005, Balmford et al. 2002). Ecological fieldwork can be an important opportunity to help students to recognise organisms and their relationships while carrying out ecological investigations. A national survey carried out in England revealed that fieldwork in biology only involved a minority of schools (Tilling, 2004). This short overview reveals some of the current challenges for an education for *reading nature* and these challenges serve as the background for the following general research questions:

- **What is a relevant level of *reading nature* for different ages of students?**
- **Which are the critical aspects for learning to *read nature*?**
- **To what extent can the ability to *read nature* be transferred between ecosystems?**

- **What are teachers' views of the importance of *reading nature*?**

With these general research questions I want to address the possible advantages of considering *reading nature* as a goal in ecology education and the implications this would have for teaching and teacher training. The questions require empirical studies on the developing ability to *read nature* and discussions with learners and teachers about the learning outcomes in relation to instruction.

6. RESEARCH DESIGN

The designing of the research is a journey taking you from formulating the field of interest to deciding how to collect and analyse your data based on an epistemological idea of learning and finding out what people know. In my case the field of interest has to do with an aspect of ecology education and the theoretical underpinnings are basically constructivist. Most studies dealing with ecological understanding do not involve the link between theory and the authentic ecosystem which is central for the ability to *read nature*. In the text below I deal with the relevant learning theories influencing my design and I discuss some aspects important for the design such as the context and the phenomenon of transfer together with the relevant age groups involved.

I will also discuss the difficulties in telling whether someone can *read nature* and relevant theories for describing this process of learning and how to evaluate this ability.

6.1 How can the ability to *read nature* be evaluated?

What is involved in the ability to *read nature* and how can one test whether a student can *read nature*? To say whether someone understands is a subjective judgement which varies with the judge and with the status of the person being judged. Knowledge varies in its relevance to understanding, but this relevance is also a subjective judgement. There are also situations when concept can mean different things to different persons but still be correct. For example a word like *energy* can mean different things to different persons. A scientist would have a definition by and large very different than that of a ten year old. To understand a concept you must have some information about it. This knowledge can be of a verbal character or as propositions (Ausubel 1968). Propositions are facts, opinions or beliefs such as that plants need light to grow. Knowledge can also be described more completely as images, episodes and intellectual or motor skills complementing the propositions as elements of memory (White & Gunstone (1992). Images are mental representations of sensory perception. Episodes are memories of events that you think happened to you or that you witnessed. Intellectual skills are the capacities to carry out different tasks which are based on memories of procedures and which can be described as verbal statements of the procedure i.e. of the motor skills which deal with how to perform it. The better integrated these skills are and the richer they are the better the capacity of knowing is. It is not easy though to rate a person's ability to *read nature* since one person can be better at one of the skills and another person superior in a different skill. One person knows for example more species than another who is more knowledgeable about the processes and who is then the best *reader of nature*? Or maybe one student is relating strongly to episodes whereas another is referring to propositions. It is also important to say that understanding of a concept is not an either or state but rather a continuum. Everybody understands something on a certain degree but we have to set some arbitrary level in order to say if a person knows it or not. To think of *reading nature* in terms of degree or level of understanding can be misleading because it implies that the knowing is uni-dimensional when the discussion about whether one person understands better than another shows that it is multidimensional. As a consequence of this you would need to assess the full set of elements the person has about the natural world to be read. In this work I have assessed students' ability to *read nature* and in order to do this I have to discriminate between the different aspects of knowledge.

6.2. What is the credibility of my findings in this thesis?

My study can be regarded as naturalistic with a phenomenological approach (Guba & Lincoln, 1994) involving four separate cases. Studying a number of separate cases in order to investigate a phenomenon can be an effective method and it is described by Stake (1998) as a *collective case study*. I follow the developing ability of reading nature in three different age groups. The instruction as well as the data analysis does not have identical design. In a fourth study I interview experienced teachers about *reading nature*. Choosing a collective case study is decided because '*it is believed that understanding them [the cases] will lead to better understanding, perhaps better theorizing, about a still larger collection of cases*' (Stake 1998 p. 437). The four groups are small and selected, rather than randomly chosen. The outline of the whole study raises questions about the credibility of the data as well as of the implications from the data. The ambition is that someone else who followed the same steps would come to the same general conclusions. In this field of research, however, the issue of reliability which has to do with whether the study is replicable or not is complicated and difficult to achieve. More important is the issue of validity and whether the study is true to the situation. It is important that the cases are credible to the teachers and the students involved. The credibility has been discussed with the involved teachers and with my supervisor during the process and these issues of methodology will be further discussed in section 12.1.

6.3. Relevant Learning theories influencing my research design

In my research I have collected data mainly by interviewing individual students or students in small groups. Students have constructed individual concept maps and collaborative fieldwork has been analysed. I have also been involved in the design of the teaching sequences. The overarching epistemological idea behind the content of the teaching design and of the analysis tools is related to constructivism. In the following text I will give a brief history of the more individual perspective of constructivism which I basically agree with but I would like to widen it and involve the importance of the social, the contextual and the motivational aspects for learning. Over the last three decades constructivist perspectives have dominated science education. Constructivism can be used in several different ways in both philosophy and education, but its most valuable function for science education is to delineate a contrast between the old transmission view of teaching and learning, and active negotiation between students and students and teachers. The basic notion of constructivism is that the student has an essential role to play in the process of constructing knowledge (Osborne, 1996; Helldén & Solomon, 2004). Constructivism has its origin in Piaget's genetic epistemology. As several researchers who have examined Piaget's work have noted (Lawson 1994; Metz 1998; Andersson 2001), he was concerned first and foremost with questions of "genetic epistemology". His focus was on biological factors and his central interest was the nature and growth of knowledge. The first core commitment of the Piagetian programme was to the idea of development. The aim was to understand how the child comes to develop complex and sophisticated ways of seeing and acting upon the world. The key word is develop in contrast to 'learn' (Erickson 1998). Piaget based his constructivist theory on humans as constructors of knowledge and that we are all born with mental structures which we develop and reconstruct during our whole life. Intellectual development is regarded as a progressive adaptation of the learners' mental structures to the surrounding environment. The work of Piaget still influences our understanding of conceptual development and learning in science education. During the 1980s and 1990s there was a focus on examining students understanding in a given conceptual domain. This field was identified in terms of 'alternative conceptions' I am not going to review either the growth of this field or the huge literature that it has spawned but the thousands of studies in this field are categorized in two comprehensive bibliographies (Carmichael et al. 1990; Pfundt & Duit, 1994). The main critique which led to a change in focus in much of science education in the 1990's was the dissatisfaction with the methods of research and the models of learning which did not take into account the importance of the context, of affective aspects and social factors influencing students learning and responses to questions (e.g. Driver, Asoko, Leach, Mortimer & Scott 1994; Duit & Treagust 2003; Schoultz, Säljö & Wyndhamn 2001; Wertsch 1998).

In my study the focus is on the individuals' ways of *reading nature* in relation to his or her earlier experiences. The teaching design is based on collaborative and individual work with the purpose of gradually constructing an understanding of the whole ecosystem through meaningful learning (Ausubel 2000). The perspective I have found to serve its purpose better than others is the human constructivist perspective on learning (Mintzes & Wandersee, 1998; Mintzes, Wandersee & Novak, 1997, Novak 1993). The human constructivist view on learning recognises that individuals' present conceptions are products of diverse personal experiences, observations of objects and events as well as culture, language and teachers' explanations. It acknowledges the role of the individual's present knowledge status as determining the quality of the subsequent learning outcome. It also recognises the dynamic nature of knowledge construction, for example regarding the earlier experiences of every individual and their impact on learning.

Human constructivism highlights the process of learning in the physical, social and personal contexts of the learner and it is consistent with the theory of meaningful learning (Ausubel, Novak, and Hanesian, 1978). This perspective emphasise the importance of the interplay taking place between feelings, personal relevance and context when people individually or in group construct meaningful concepts and understanding. Constructing these common meanings and explanations is an important goal in teaching which makes it possible for the teacher and the learners to exchange ideas and thoughts based on a common platform of understanding. As we see in the concept map (Figure 5) the assimilation theory is central and support Piaget's view on the learning as an internal process based on cognitive conflict. This means that the one who is learning actively expands her understanding of a concept or finds new explanations for the concept. To obtain successful learning the student must acquire knowledge actively and establish relations between what is learned and what the student already knows. This distinguishes between meaningful and rote learning which Ausubel regards as arbitrary and carrying little value for developing an understanding of a phenomena (Ausubel, 2000). Learning becomes meaningful when the learner is given opportunities to relate, and choose to relate, new knowledge to prior knowledge in a non-arbitrary and substantive way. When meaningful learning occurs the connections between the concepts become more precise and better integrated with other concepts. In Ausubel's view, much of meaningful learning can be explained by a process he calls *subsumption*. This is when new and more specific concepts are linked to the more general concepts the learner already knows. A relevant example of this is when the student realises the common characters for a group of organisms such as pillbugs by learning more about their morphology and behaviour. As it is illustrated in the concept map (fig.5) superordinate learning can follow from subsumption. By superordinate learning Ausubel means that new and more general and powerful concepts are acquired that subsume existing ideas. An example of this may be when the students realise how the pillbug relates to other animals in a relationship that can be described as a food chain which is the new and powerful concept. In the concept map (fig 5) there is also a link between subsumption and progressive differentiation. By progressive differentiation Ausubel refers to the gradual elaboration of concept meanings that occurs during subsumption and superordinate learning, resulting in more precise and/or more elaborate ideas. In *reading nature* this is when students experience different phenomena in an ecosystem which together make sense of the processes in nature, for example regarding both mosses and trees as important producers in the forest. The other concept of this epistemology is integrative reconciliation, or resolutions of conflicting or ambiguous meanings or concepts and propositions which will lead to the assimilation of the new experiences. Thus, meaningful learning is knowledge construction in which students also seek to "make sense" of their experiences.

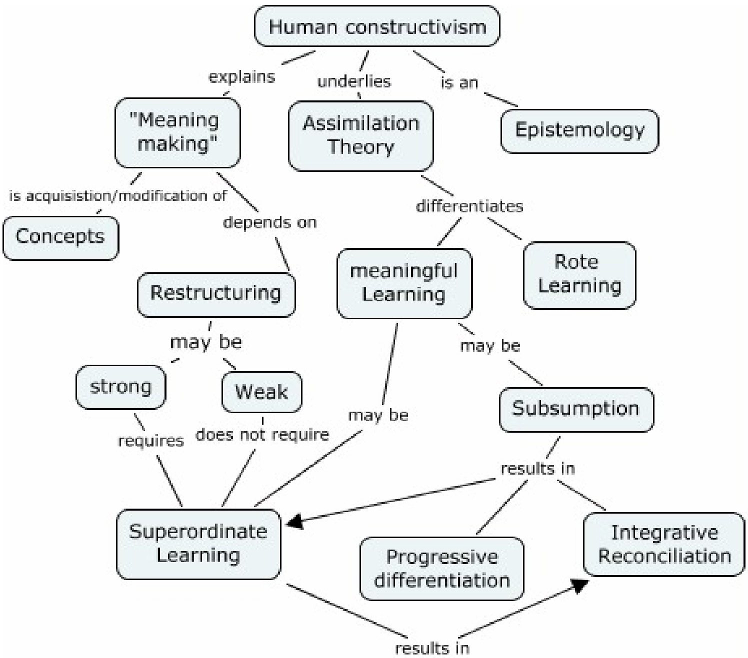

Fig 5. Concept map of Human Constructivism from Mintze & Wandersee (1998)

Basically human constructivism means that the learner has to be an active constructer of knowledge when for example seeing how organisms in a river are adapted to the fast stream which involves earlier experience of different forms of animals and of their specific needs to survive. Linking what you observe to what you already know with an underlying assumption of how it all should relate are important aspects of human constructivism. The perspective has a strong foundation in a psychological theory of learning i.e. meaningful learning. With this perspective comes a tool which I have frequently used in my research- the concept maps.

6.4. Concept maps as a tool for analysing students understanding

In the attempt to illustrate and analyse students understanding of complex phenomena in science Novak constructed the first concept maps (Novak & Gowin 1984). Three ideas from Ausubel´s assimilation theory emerged as central to this thinking. 1) The development of new meanings as building on prior relevant concepts and propositions. 2) Cognitive structures as organized hierarchically, with more general, more inclusive concepts occupying higher levels in the hierarchy and more specific, less inclusive concepts subsumed under the more general concepts. 3) When meaningful learning occurs, relationship between concepts become more explicit, more precise and better integrated with other concepts and propositions. These ideas were the foundation for the idea to translate interview transcripts into hierarchical structures of concepts and relationships between concepts. This idea developed into the invention of the first concept map. Novak and his colleagues found that concept maps were effective as a way of reducing large amounts of interview data without loosing the core concepts and understanding presented by the interviewee.

Schmid & Telaro (1990) wrote "*Biology is so difficult to learn because it consists of a myriad of unfamiliar concepts involving complex relations. The school's favoured approach to teaching unfamiliar material is rote learning. Rote learning predictably fails in the face of multilevel, complex interactions involved in biology. Concept mapping stresses meaningful learning, and appears to be ideally suited to address biological content*"(p.82).

Concept mapping can also be a highly flexible tool that can be adapted for almost any learning group, where the learner is designing his/her own concept map. The traditional format is where the concepts are given in boxes and linked by labelled arrows. The most inclusive concepts appear towards the top of the map, with more subordinate concepts towards the bottom. Each concept can only appear in one place on the map but it may be linked to any number of others. Concept mapping with its graphical structure has been recognised as a powerful tool for helping students understand the notion of complex models such as ecosystems (Kinchin, 2000). The technique is explicitly grounded in Ausubel's assimilation theory of learning, of which the central idea is that of *meaningful learning* (Ausubel 2000) The use of concept mapping in schools can help students to gain more unified understanding of a topic, organise their knowledge for more effective problem solving, and understand how they learn (i.e. become more metacognitively aware). It has been suggested that the promotion of meaningful learning resulting from concept mapping can act to reduce subject based anxiety and over-come differential gender related performance with respect to learning and achievement in science (Kinchin 2000; Anderson, Lucas & Ginns, 2003).

Although these graphic representations can reveal the complex webs of students' ideas, when ideas are taken out of the context of students' wordings and reduced to conceptual labels the labels become open to a variety of interpretations and meanings that may not accurately represent the meanings or richness of students' ideas. Research has indicated that students often find it difficult to make these concept maps and that the difficulties not necessarily have to do with their understanding of the topic studied but rather that the instrument suits some students better than others (Schmid & Telaro, 1990) . Experience in using hierarchically constructed maps in science education shows that the maps were more successfully utilized as the student's experience in drawing that type of map grew (Novak, 1998; Novak & Govin, 1984). Novak makes the following reflection with regards to the evaluation of the concept maps in relation to written tests: "*Although there is some subjectivity in scoring the maps, the great freedom given to individuals to demonstrate their idiosyncratic meanings for the subject matter removes an important source of bias and subjectivity that is present when the test* *writer chooses the specific content and form in which answers must be selected*". (Novak, 1984, p.194).

Looking back at the text above I have described human constructivism as a psychological model for learning. The focus lies on the process of meaningful learning and how it changes our understanding on an individual plane. I have also described concept mapping as a tool enhancing meaningful learning. During concept mapping the concepts are usually known by the learner. The challenge is to combine them in a clever way in order to say something about how they are related to a whole. This is important but there is an earlier step in the learning process which has to be looked at. This has to do with the conditions necessary for meaningful learning to take place and what it is that makes the students see the world with "new eyes" and discern objects or ideas which were there all the time and giving them another meaning. For this process I believe the theory of variation (Bowden & Marton, 1998) is relevant and complementary to human constructivism. In Carlsson's (1999) study on ecological understanding she used a phenomenographic approach in her search for qualitatively different ways of experiencing ecological understanding. In her findings she looked at the ability of the students to discern the relevant aspects of for instance photosynthesis in relation to the carbon cycle. She designed a number of probes according to the theory of variation and the relation between discernment, variation and simultaneity.

6.5. Theory of variation as a complement to Human constructivism

The theory of variation (Bowden & Marton, 1998) is about how we gain knowledge of the world. According to the theory, experiences and learning should be understood in terms of three notions, discernment, simultaneity and variation. It has to do with experiencing something in a certain way.

"*To experience something implies discerning it from the context which it is a part and to relate it to that context or to other contexts. To experience something also implies discerning the parts of what we experience and relating these to each other and to the whole*" (ibid. p. 30)

Discerning something, irrespective of it being a concrete organism in nature or an abstract theory or a relationship, requires that it is exposed to variation. We need to know that there are several different kinds of yellow flowers in the meadow to be able to recognise a dandelion from a buttercup. Without this awareness it would just be a yellow flower. It is only when an aspect is exposed to variation it becomes accessible to discernment. Every aspect can be a dimension of variation, and the ability to discern a critical aspect is seen as a function of the variation that is experienced in the dimension, which corresponds to that aspect. According to Bowden and Marton (1998): When some aspect of a phenomenon or an event varies while another aspect remains invariant, the varying aspect will be discerned. In order for this to happen variation must be experienced by someone as variation and there has to be a simultaneity presence of different dimensions.

The development of *reading nature*, according to this line of reasoning, has to do with differences in ways of seeing various structures in nature as meaningful patterns. Bransford et al. (2000) stated that expertise in a domain is characterised by sensitivity to patterns of meaningful information that might not be available to others dealing with the same problems within the same domains. As an example they mentioned how physicists are able to see that the problems of river currents and the problem of headwinds and tailwinds in airplanes involve similar physical aspects of relative velocities. The capability of acting in powerful

ways within a certain domain, is reflected in the various ways of seeing, i.e. the various meanings seen in a particular scenario or problem. Powerful ways of acting derive from powerful ways of seeing, and the way something is seen or experienced is a fundamental feature of learning (Marton & Tsui, 2004). Consequently, arranging for learning implies arranging for developing learner's ways of seeing or experiencing, i.e. developing the eyes through which the world is perceived. Since we experience the world in different ways the instruction according to Ausubelian terminology (1968) has to do with the starting point of the learner: *"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly* (p. IV) Instruction must focus on giving the learner new experiences of the world and presenting it from different angles. In this perspective the context is important. The outdoor environment offers great opportunities to discern variation. Often the task for the instructor is to guide the student to discern the relevant variation which may help an understanding of a phenomenon. An important educational issue that may arise from this is to what extent the experienced variation in one context can transfer to another context and be supporting the learning there?
As I mentioned in my preface I have met several people with outdoor experience who cannot discern the variety of organisms in nature. This does not only require outdoor experience but also someone more knowledgeable who can guide them to discern this in nature.

6.6. Transfer- what abilities can be generalised between different ecosystems?

Transfer is about how what is learned in one situation affects or influences what the learner is capable of doing in another situation. The relevance of this issue is supported by a critical glance at the national curriculum where students are expected to be "familiar with several ecosystems". If being "familiar with" means being "able to *read nature*" it is important to study what they can transfer. Studying each of these ecosystems in great detail would be very time consuming and probably not feasible. If, on the other hand, students can generalise a large proportion of their ecological understanding between different ecosystems this may be an argument for studying a single ecosystem in great detail.

Historically, research into transfer dates back to the early 20th century when for example the behaviourist Thorndike explained that transfer occurs to the extent to which original learning and transfer situations share identical elements – or common stimulus elements (Lobato, 2006). With the cognitive revolution the notion of identical elements was reformulated as mental symbolic representations. Studies of transfer consisted of defining/identifying similarities across two tasks and then seeking evidence (or lack thereof) for transfer. Results were binary saying if transfer happened or not. Expanded views of transfer (Lave & Venger, 1991, Greeno, Smith & Moore 1993) differ from the traditional views by investigating the mediating factors by which individuals activate and apply prior learning, both productively and unproductively during transfer tasks. This of course reflects their sociocultural view of learning where situated cognition is central. Lave (1988) for example found that educated adults did not apply school-based algorithms to make comparisons when shopping. Based on this evidence she argued that transfer does not occur across cultural settings. (e.g. from school to everyday life). Given the classic definition of transfer, Lave's argument makes sense. Within a situated cognition perspective Greeno et al. (1993) suggest that transfer is also mediated by factors such as interactions with the environment, teachers, peers and other external influences. If we draw this ontology to its extreme, studying the ability to transfer the ability to *read nature* between different ecosystems would be irrelevant since knowledge is situated and therefore cannot be transferred between contexts.

I find support in (Hammer, Elby, Scherr & Redish, 2005) description of a more complex view of transfer. They refer critically to the view of knowledge or ability as a *thing* the individual acquires in one context and may bring to another. Their approach is founded on a manifold ontology of mind, of knowledge, and of reasoning abilities as comprised of many fine-grained resources that may be activated or not in any particular context. Like Greeno et al. (1993) they are sceptical of treating knowledge or abilities as things one acquires and manipulates as intact units. Rather they see knowledge and experience as emergent, analogous to other emergent phenomena in complex systems in which the things we see, such as an ecosystem, emerge from many small agents acting in local concert.

Scientific understanding frequently involves comprehending a system at an abstract rather than a superficial level. Biology teachers for example want their students to understand the genetic mechanism underlying heredity and not simply the differing colours of different pea plants. This means focusing on abstract principles which are represented by visual objects in nature and finding laws that govern the appearance of similar objects in different ecosystems. Linking superficial appearances to extract deep principles is as critical to science as it is difficult to achieve (Goldstone & Sakamoto, 2003). These deep principles are often called "schemata" and are important for high level cognition because once they have been acquired they can be applied to a wide variety of subsequent problems (Goldstone & Sakamoto, 2003, Bransford, 1999).

A critique of transfer research was that the criteria of what was transferred was already decided in advance by the researcher. As a reaction to this Lobato (2003) explored what kind of transfer took place thanks to the similarities that learners have established between two or more situations. In my research I would like to adopt this more open approach towards studying what the students actually transfer.

If we shortly return to Marton and the theory of variation, research has indicated that transfer across contexts is especially difficult when a subject is taught only in a single context rather than in multiple contexts (Marton, 2006). When a subject is taught in multiple contexts, however, and includes examples that demonstrate wide applications of what is being taught, students are more likely to abstract the relevant features of concepts and to develop a flexible representation of knowledge (Bransford et al, 1999). In line with this the design of my study and of the learning situations for the students would have to include instruction both in- and out of doors together with learning and evaluating students understanding in different situations and using different methods.

I have so far described the background theory relevant for the planning of my research design. Now I would like to move from discussing the probing of students abilities to the epistemological ideas concerning how I believe students learn to read nature and how this has influenced the teaching design.

6.7. The outdoors as the natural context for *reading nature*

Already in the preface I mentioned the difficulties I was causing people when I asked them to describe and explain what they saw in the surrounding nature. This question demands that they can *read nature* according to my earlier description of the abilities involved.

In a research project dealing with *reading nature* it is the natural thing to collect the data on students' abilities in an outdoor context. In preparation for this research project I read a large number of studies in ecological education. Several of them deal with the importance of fieldwork in ecology education (e.g. Slingsby et al, 2001; Dillon et al . 2006). According to my review there are very few studies where they probe ecological content knowledge and understanding in the outdoor context. In my work the context for the interviews with direct relation to the living objects is of greatest importance for the relevance of the data. The importance of the staging of the interviews will be discussed further in section 7.2. Boulter, Tunnicliffe and Reiss (2003) did a study to determine the extent to which the revealed understandings young people have of objects in the natural environment depend on the research instruments used. The students were interviewed indoors about common objects such as a tree or a pigeon using an oral probe, a drawing or a photograph of the object. They were also interviewed in an out-of-school setting (oral probe). Their results show the importance of the probe where the oral probes opened up for a richer discussion about the object and its biology. What their study also showed was that the out-of-school context where they used group interviews triggered social rather than informative talk and that students did express their ideas in a less structured way. Their results are challenging and encouraging for the design of my research.

Another reason for choosing reading nature with its outdoor focus has to do with the growing concern about the substantial decrease in opportunities for outdoor learning in schools (e.g. Dillon et al. 2006; Rickinson et al. 2004; Slingsby & Tilling 2002,) and the limited knowledge students have of our common animals and plants in the nearest environment (e.g. Bebbington 2005). In the national curriculum for compulsory schooling in all Nordic countries there are explicit paragraphs saying that primary school students (up to year 5) should be taught about common animals and plants and about their environmental demands. It is also stressed that students should be taught about different ecosystems. However, in these curricula there are no explicit guidelines for how this instruction is supposed to be carried out and naturally there is a great variation in how teachers meet these demands.

If I now turn from the content knowledge to the factors influencing students' learning I believe in the importance of field work where first hand experiences in authentic environments are paramount. This is supported by a concluding remark from the empirical data of a large review on outdoor learning by Rickinson et al. (2004):

"*fieldwork can have a positive impact on long term memory, due to the memorable nature of the fieldwork setting and there can be reinforcement between the affective and the cognitive, with each informing the other and providing a bridge to higher order learning" (p.9).*

In the same review the researchers claim that there is a need for qualitative studies on students learning in the outdoor context especially with a focus on their ability to apply theory to the authentic context, which is a support for the goal of my study.

The importance of combining affective factors and cognition is supported by Nundy who studied the relationship between affective and cognitive domains and concluded that gains in one domain reinforce gains in the other (Nundy 1999; Nundy 2001). The importance of fieldwork styles for long term memory structures was studied by Mackenzie and White (1982). They compared teaching strategies in a geography course on coastal processes in lower secondary school. The researchers found a positive correlation between fieldwork and learning in general but in particular they found that excursions or fieldwork which encouraged processing and produced strong linking of episodes with content knowledge improved students understanding in general but their long term retention of knowledge significantly. The importance of recognising the differences between the episodic and the semantic memories have also been discussed elsewhere (e.g. Helldén & Solomon 2004). Narratives and personal relation to the scientific content is considered an important aspect of cognitive science and scientific literacy (Klein 2006) and the concept *reading nature* certainly is an example of this. My view of the importance of the outdoor context for learning to *read nature* is related to my view of transfer and of human constructivist learning where the multiple contexts and different examples eliciting the same ecological phenomena together with the affective, meaningful learning and discussions with peers during field work are important.

6.8. Data collection

Reading nature involves multiple and interactive competencies as was shown in figure 4. What type of methods can be used for probing students' ability to read nature? Different methods are designed to access different aspects of student reasoning. Driver and Erickson (1983) have made the distinction between phenomenological and conceptually based approaches. Phenomenological approaches to probing students' thinking involve presenting students with events or systems and asking them to make predictions and give explanations for the way things happen, or what they see. No restraint is placed on the way the students respond as they talk about the phenomenon, using names or conceptions of their own choice. The Piagetian clinical interview is the classical example of such an approach. This is an approach where students' knowledge is in focus and it is the student who selects the language or examples to communicate and which order to discuss things.
Conceptually based approaches to probing students' thinking, on the other hand, focus on aspects of the students' propositional knowledge structure. Typically words, or propositions are presented and students are asked to perform a specific task with them. A paper and pencil test on students ability to explain a scientific phenomena by choosing one out of a number of possible answers (Andersson, 1990)

Basically a phenomenological approach has been taken to probe students' ability to *read nature*. The main source of data has come from semi-structured interviews. Concept maps and video recorded fieldwork have often supplemented the interview data.

In section 4, I presented the general research questions which guide the design of the whole study. These questions attack the issue of *reading nature* from a broad perspective. In the discussion of my results I will return to the general research questions again. Before that I will present the four separate case studies. Each of them has its own focus and age group and for each study there is a specific research question which has been refined from the general questions. The specific research questions are linked to the phenomena that I actually want to collect empirical data on. The papers from the studies will be briefly presented here. In the following discussion the results from the four papers will be dealt with across the studies and referring back to the general research questions.

6.9. Sampling- who are the respondents and how are they chosen?

The collection of data was conducted with four different respondent groups: three student groups and a group of experienced teachers. In the first paper a class of student teachers were chosen. In preparation for the study I had coined the notion *reading nature* but I had not fully decided on the competences. I wanted to use an inductive method to set the standard for what to expect from students regarding the ability to *read nature*. They were all student teachers in mathematics and science for school years 4-9. The reason for choosing university students for the first study apart from the framing of standard is I had positive experiences from interviewing student teachers in former studies. I found them generally outspoken and cooperative. It is important to say is that I had not met this class before so they were not familiar with me.

In the second paper I followed a class of lower secondary students in years 7-8 (13-14 year olds). The main reason for choosing this age group was that they are part of the compulsory schooling with classes of mixed abilities and interests. I could have chosen students from upper secondary school, where I have more experience as a teacher myself, but I wanted to turn to the broader group of students who all have the same biology curriculum. The specific class was selected since I was familiar with their science teacher but I had not met the students before.

The third paper is based on a study of primary school students, years 3-4 (10-11year olds). My experience from years of outdoor education and field studies with this age group is that they are often very positive and rewarding to work with. They can normally draw and write well and you can expect them to design their own experiments and evaluate the outcome. These are all important abilities required in my teaching sequence. The class was chosen for practical reasons since I was familiar with their teacher and some in the class knew me vaguely since I had my daughter in another class at the school.

In the fourth paper I discussed *reading nature* with a group of experienced primary school teachers. The aim of the paper was to present their ideas of *reading nature* as a goal in education and their view on students' development according to a video sequence from the instruction in the primary class in paper III. These teachers were selected by the school administrators of the municipality and the criteria were that they should have at least 15 years of teaching and they should have experience of outdoor education without being specialised in this field. They should also be outspoken and critical regarding educational issues.

7. RESEARCH METHODS

7.1 Interviews

In all four articles interviews were used to acquire information. Interviews are rich sources of information and can add nuances to and complement concept maps or recorded peer discussions during field work. As Kvale states "If you want to know how people understand their world and their life, why not talk to them?" (Kvale, 1996, p.1.) Interviewing in general, its benefits and problems has been discussed in detail elsewhere, therefore, it will not be recapitulated here. For a more detailed account of this see Cohen & Manion, 1995, Ginsburg, 1997; Kvale 1996. I will discuss some of the characteristic features of the interviews in my articles. A research interview is a specific verbal interaction, with initiated purpose, focussing on a specific content area. In my research the interview formats used can be described as semi-structured, or open with an interview guide. Despite the different contexts for the interviews, being mainly out in the ecosystem, I always used an interview guide starting with broader more open question followed by more and more specific questions. Depending on the progression of the interview the questions could follow in a different order but all the interviews covered the same main issues decided in advance. A research interview is always content oriented and it tries to capture the meaning of what is explicitly said, and what is tacit between the interviewer and the student. The outcome of an interview analysis is highly dependent on how openly the researcher can look upon the results, which presupposes a critical awareness of one's own assumptions and ideas to avoid colouring the analysis by the personal point of view. The strength of interviews are the direct contact with the person from which information is collected, and clarifying questions can be asked immediately during the interview. Another advantage, at least with open ended questions, is that the unexpected can surface and spontaneous reflections of prior learning situations or influential everyday occasions have been shown to have a strong impact on a person's understanding (Helldén 1995, 2004). The method holds many pitfalls for validity to be avoided. Asking leading questions is often necessary but this is not the same as guiding the person to the correct answer. Making the interviewee feeling comfortable with answering the questions without influencing what they say is difficult and often develops through experience. A major problem is that they are time consuming, especially in the analysis phase.

7.2. The staging of the interviews

In ecology education several studies have been conducted using interviews with the aim of describing students understanding or developing understanding of large scale ecological processes such as energy transformation or cycles of matter in nature (e.g. Leach et al 1996, Carlsson 1999, Helldén 1992). The focus was on understanding the qualities of the phenomena. In order to help students focus on the question or challenge their ideas these interviewers used artefacts such as objects or metaphors. The staging of the interviews, with its possible artefacts, can be of great significance to the outcome. Schoultz et al. (2001) have for instance shown that when students who discussed the shape of the earth and other central astronomical concepts were provided with a globe as an artefact they could give a much more complex and scientifically correct response than without it. Along this vein, but in an ecological context Leach et al. (1996) discussed with young students the process of decay in the light of a sequence of pictures of a rotting apple. In my work data was collected mainly in the outdoor context, which hardly could be regarded as an artefact, rather the opposite, but it influences the outcome of the interview. *Reading nature* has to do with the interpretation of authentic objects in nature and therefore it is necessary to study this ability in direct contact with nature. And when it comes to the analysis of data it is as Lemke (1988) pointed out when he described discursive analysis, the answers have to be analysed in relation to the context. Different ecosystems have certain features in common but also features unique to each ecosystem.

As a final remark I would like to stress the importance of creating an as friendly and positive interview climate as possible. Helldén (1992) stressed that it is what the interviewees think about a phenomena irrespective of how this relates to the scientific view of it that is the interest and not whether it is correct or not. By asking "*what do <u>you</u> think about this*" is a way of avoiding the interview turning out to be an interrogation with correct or faulty answers.

7.3. Concept mapping as a way of evaluating student's understanding

In section 6.4 I discussed the limits and advantages of using concept maps in instruction, but here I would like to briefly describe the method as a metacognitive tool for the learner and at the same time a tool for analysis for the researcher. Concept maps are graphical tools for organising and representing knowledge. I have on several occasions asked students to make individual concept maps or to link objects together in a meaningful way. Their reasoning and their final concept maps have been a source of information about students' understanding. Concept maps can be analysed both quantitatively, where the links and cross links are counted and the pattern of the map is in focus. They can also be analysed more qualitatively where the content of the whole map and the quality of the links is what counts . This latter form of analysis is what I have used in this study.

8. ANALYSIS OF DATA

My description of the competencies involved in *reading nature* and the complex notion of understanding has implications for its assessment. Knowledge is complex and to assess it adequately by any single style of test and a single numerical score cannot satisfactorily represent a person's ability. Assessing the ability to *read nature* is by no means an exception to this. I have considered three different analysis tools. These three are a bi-dimensional coding scheme (Hogan & Fisherkeller, 1996), the SOLO taxonomy (Biggs & Collis, 1982) and the Structure-Behaviour and Function analysis (Hmelo-Silver & Green-Pfeffer, 2004).

8.1. Bi-dimensional coding scheme

My experience from informally talking about ecology in the field with people of different ages is that they in general find it difficult to relate the theory of ecology to their real world impressions of nature. This is of course crucial for *reading nature* and this is what I want to find a method for analysing. Hogan & Fisherkeller (1996) were struggling with the same type of dilemma when they wanted to portray young students' quality and depth in understanding decomposition. They combined the dimension of compatibility with expert views on the one hand and on the other hand the dimension of elaborateness of students' reasoning. This second dimension did not account for the correctness but rather the complexity in students' reasoning. Their presupposition was that it was important to elicit students' way of reasoning together with their compatibility in order to design future instruction. What I did was to revise their bi-dimensional analytical tool to fit my purpose. The two dimensions I wanted to study were again compatibility with expert views and elaborateness of reasoning. This second criteria would now focus on how well the theory was linked to structures in the ecosystem where the interviews were conducted.

Hogan & Fisherkeller were dealing with one concept, difficult as that is, but I want to analyse a more complex understanding, or ability. I decided to divide the ability into three separate parts analysed separately. These were the organisms and non-living factors, the cycles and processes and finally the human influence.

In my coding scheme the compatibility dimension has the following grades:

C *= Compatible. Statements agree with expert propositions;*
G *= Generally sound with a few (minority) statements not agreeing with expert propositions*
I *= Incompatible. Statements disagree with expert propositions.*

In this dimension I needed to correlate statements to expert ideas of the topics. The expert criteria was negotiated with experts in the field and has to contain relevant content knowledge. High achieving learners are expected to reach this level after the course. The second dimension is dealing with how well they can relate their description and explanation of the ecosystem to what they see in the ecosystem. Criteria for the second dimension are:

E *= Elaborate. Statements relate to the ecosystem in a complex and holistic way with many examples.*
S *= Sketchy. Only few details and logic given. Only few links to the ecosystem.*
N *= Non-linked. Statements are not linked to the ecosystem. Rather like school-book content presented out of context without correlation to surrounding nature.*

My coding scheme is different from that of Hogan & Fisherkeller in the sense that I have three grades for each dimension instead of the original two. The reason for this is to make the analysis more precise. I have also changed the second dimension from describing the consistency of their reasoning to how they can link the propositional knowledge to the real objects in nature.

8.2. Structure-Behaviour- Function analysis

In order to be able to break down data from interviews or field activities into manageable units a Structure- Behaviour-Function-analysis can be fruitful to use. *Reading nature* can be divided into three levels of abstraction – the structure, the behaviour and the functional level (SBF). However clear the representation, there remain wide variations in interpretations by the learners. Nature does not come with labels and outlines. The novice may not see the parts of the phenomena while the experts see them easily and know the behaviours of these parts as well as the causes of the behaviour. In a study of experts compared to novices' understanding of an aquatic system, an aquarium, a SBF-based coding scheme was used by Hmelo-Silver & Green-Pfeffer (2004). This framework allows effective reasoning about the functional and causal roles played by structural elements in a system. It is done by describing a system's subcomponents (structures), their purpose in the system (functions), and the mechanisms that enable their functions (behaviour).

- **Structures** refer to the elements and physical structures of a system (e.g. trees, mosses, insects, light and water are some of the elements that comprise an ecosystem).

- **Behaviours** (mechanisms) refer to how the structures of a system achieve their function. These are the mechanisms or interactions that yield a product, outcome or reaction. They describe the dynamic and often invisible processes that are difficult to represent. (e.g. plants turn water and carbon dioxide into carbohydrates and oxygen gas). Behaviour refers to the dynamic mechanisms that cause changes in the structural state of a system.

- **Functions** refer to the function of an element in a given system (e.g. plants produce oxygen and food or worms are decomposers in the forest.)

Their results indicated that novices' representations focused on perceptually available, static structures of the system, whereas experts integrated structural, functional and behavioural elements. I found SBF to be a mode of analysis relevant for my purposes since it focuses on causal understanding of the relationship among different parts of the system.

8.3. SOLO-taxonomy

SOLO-taxonomy (Dart & Boulton-Lewis 1998; Biggs & Collis 1982) was designed to be particularly relevant to school and university learning environments, with the central feature being a focus on the structure of students' responses after a teaching sequence. It offers a model for characterizing levels of sophistication of children's developing conceptions and hence explanations. The SOLO taxonomy focuses on sophistication and does not necessarily equate with conventional scientific ideas. For reasons of congruence with the previous analysis tools I have added an aspect of ecological correctness to the five SOLO levels. The levels of my revised SOLO taxonomy are described below.

1. **Prestructural.** The responses are often inadequate and the student is frequently referring to irrelevant aspects.
2. **Unistructural**. Single aspects of the task are picked up, but the task itself is not attacked in an appropriate way. The student reasons in the relevant mode but only in single step relations without any mediating description of a sequence of causally linked events or relations. This level of explanation indicates fragmentary understanding without any attempt to make a synthesis or systemic analysis of the ecosystem.

3. **Multistructural**. Causal chains are given in the explanations, linking two or more objects together and referring to relevant ecological theory. There is no attempt, however, to raise the explanations and linking to the level of a generalization. No process or abstract relations are discussed.

4. **Relational**. Relational explanations extend relevant points to a general principle, or interrelationship between factors.

5. **Extended Abstract**. The coherent whole can be generalised on a concrete as well as an abstract level to other ecosystems.

The three analytical tools have slightly different focus. The first is aiming at correlating students ecological understanding with their ability to link the theories to the objects in the ecosystem. The second tool is used to analyse and describe how elaborate the students can read nature with the assumption that more complex ability is linked to reasoning on a more functional and behavioural level. The third tool is going one step further in the analysis of the sophistication of students reasoning in nature. The ability to *read nature* is related to age and experience and, of course, a biologist reads nature differently from a primary school student. The SOLO levels have therefore been adapted to the relevant age group.

In the table below I present the different methods and tools for collecting and analysing data across the four case studies. In the upper part is the method of data collection and below this is the analytical tool. The table shows that interviews are the dominating method for collecting data and used in all four studies.

Table 1. Summary of research tools and methods for data collection in the four papers.

Data collection and analytical tools				
	Paper I	Paper II	Paper III	Paper IV
Age group	Student-teachers	Students yr 7-8	Students yr 3-4	Teachers
Number of participants	**18**	**15**	**23**	**13**
Type of data:				
• Interviews Individual	**x**	**x**	**x**	**x**
Group	**x**			
• Concept maps		**x**	**x**	
• Video recorded fieldwork		**x**		**x**
• Questionnaire	**x**			**x**
Analysis tool:				
• Bi-dimensional coding scheme	**x**			
• S-B-F – analysis		**x**		
• SOLO- taxonomy			**x**	

9. RESULTS

In this section I will present a summary of each of the four papers. The summaries include the data collection, data analysis and the findings. Following from the overview of each paper there is a section of the results related to the specific questions raised in the separate papers.

The papers are linked in a sequence.
The sequence of papers starts with student teachers and their ability to *read nature* and their views on important factors influencing their learning. The findings have influenced the design of the subsequent studies with secondary students and with primary students. Finally a group of experienced teachers have commented on the importance of *reading nature* in relation to the study on the primary students. Starting with the more knowledgeable learners has helped me to judge what is relevant and reasonable to attain for the less experienced. It is always easier to do this judgement if you can relate to what a more experienced person can do, than the other way round. It is also useful to have this information when designing the teaching sequences and deciding on what to include in the teaching.

9.1 Summary of papers

9.1.1. Paper I

Student-Teachers' Ability to *Read Nature*: Reflections on their own learning in ecology.

This study involved 18 student teachers in their fourth year on the university program for science and mathematics teachers in school years 4-9. The students were interviewed in groups of two or three before the course started. The interviews were conducted in a forest habitat where they were asked to describe what they saw in the forest and explain why it looked the way it did. They were also asked to describe the human impact on the ecosystem. After ten weeks, when the course had finished the interviews were repeated. The pre- and post course interviews were tape recorded. Each student was given a tape with the two interviews. They were asked to listen to the tape and reflect on their own learning, on important learning instances and on their ability to *read nature*. The third interview was a metacognitive individual interview conducted indoors dealing with the issues mentioned above. The outdoor interviews were analysed to describe students developed ability to *read nature*. The data was analysed using a modified bi-dimensional coding scheme (Hogan & Fisherkeller, 1996): The two dimensions were correctness in relation to expert views and ability to relate ecological theory to the real structures in nature. The main findings were that the groups developed an elaborate and mainly scientifically correct understanding of the organisms in the forest and they often linked the naming of the organisms to the abiotic factors such as light or nutrients in the soil. The second topic was cycles and processes which was difficult for the students to link to what they saw in the forest. Generally they had a good grasp of the processes theoretically but the problem was to link the theory to the authentic structures of the ecosystem, which of course is an important part of *reading nature*. The third topic was the ability to see the human influence on the ecosystem. Initially most students had difficulties seeing the traces of direct human influence such as logging or introduced species and indirect influence such as acidification was even more difficult. In the second interview they often could elaborate on what they saw in the ecosystem as an effect of human influence but the underlying theory for this influence was not always compatible with expert views.

From the metacognitive part of the study there are three main findings, standing out as important for most of the students: the development of a new language- Ecologish- as part of entering the new discourse. The taxonomy leading them to see the world with new eyes and finally the excursions as highly important events for learning ecology.
The combination of studying the organisms within the ecosystem and having a chance to discuss the ecology during field studies was considered to be of key importance for a majority of the students. All of the students found *reading nature* as an important ability for a biology teacher but some of them said it was difficult to achieve.

9.1.2. Paper II

Reading new environments. Students' ability to generalise their understanding between different ecosystems.

This study involved 15 secondary students in a grade 7-8 class (13-14 yrs). The aim was to investigate students' ability to read nature in a forest ecosystem after instruction and to investigate their ability to transfer their knowledge to a different ecosystem. A teaching sequence was designed. It started with the large scale processes and abstract phenomena such as energy flow and cycling of matter in an ecosystem. From this point of departure the content of instruction was mainly field based with investigations of the common plants and animals and their interrelations and their relations to the large scale processes together with a discussion of the human impact in the forest. This is regarded as a top-down approach to instruction. The design of the instruction was negotiated between the researcher and the class teacher and included several excursions to the nearby forest. Instruction was given by the class teacher and student learning was investigated by using several different methods. Each student was interviewed before and after instruction in a forest ecosystem. As a metacognitive tool for the learning students as well as an important part of the research data students made two individual concept maps. One of the maps was illustrating photosynthesis and energy flow and the other map described the forest as an ecosystem. Students were also video recorded in small groups during fieldwork when they constructed a miniature forest ecosystem in a sealed glass aquarium. All the data was analysed and student development was presented along categories grounded in the collected data. The categories dealt with naming of organisms and relating them to functional groups, trophic relationships within the forest, energy flow and cycling of matter, human impact and natural succession.

Two months after instruction each student was taken to a pond where they were asked to compare this ecosystem to the forest. This transfer interview was followed by a field activity where the students designed and created a miniature aquatic ecosystem by the pond. The transfer interviews were aiming at analysing students' ideas of the relationship between abstract principles and superficial structures when they are trying to read the new environment. In order to be able to break down data from the transfer interview and field work into manageable units of knowledge, such as schemata, a Structure-Behaviour and Function analysis (Hmelo-Silver & Green-Pfeffer, 2004) was used.

The main findings from the pre-course interview were that all students initially had difficulties relating the abstract processes to the ecosystem structures they saw in the forest such as animals or plants. In the transfer interview they could refer to similar structures of the two ecosystems recognising functional groups in the new ecosystem. On the behavioural level where they need to describe how the abstract processes function many of the students had difficulties discussing the flow of energy and cycling of matter in the new ecosystem.
The results indicate that the recognition of functional groups such as predators or decomposers together with understanding of the model of a food pyramid and of the energy as packaged into the plants during photosynthesis and then conveyed to the eaters of the ecosystem were effective metaphors helping many students to read the new ecosystem. Students seem to have difficulties when they do not recognize the names of several animals and they also have great difficulties discussing the human influence in the new environment.

9.1.3. Paper III

Reading nature from a bottom-up perspective.
This paper reports on a study of a grade 3-4 class (10-11 yrs) when they followed a teaching sequence aimed at helping them to *read nature* in a river ecosystem. The teaching sequence had a bottom-up approach in the sense that it was taking as its starting point a single organism in the river- the freshwater shrimp. I found, along with other researchers (Leach et al. 1996, Carlsson, 2002, Wood-Robinson 1995) that students have difficulties with learning the abstract phenomena such as photosynthesis. The underlying assumption for the bottom-up design was that a deeper knowledge of an organism and its ecology can help students to link it to the organisms and to the more abstract principles of systems ecology. The aim of the study was to investigate in which qualitative ways the students were linking their knowledge of a key organism to the reading of the river. Individual interviews were conducted three times with pre- and a post course interview together with an interview half way into the teaching sequence. It has been shown (e.g. Schmid & Telaro, 1999) that concept mapping is difficult for younger students and that it is a skill which improves with practice. With 10-11 year olds I decided not to ask them to make concept maps but instead I used tray-interviews. Students were presented with a tray full of living and non living objects from the river together with pictures from the river. They were asked to link the objects on the tray in as many ways as possible and explain how they think they are related. The video recorded tray interviews were transcribed as concept maps. To analyse the level of sophistication of student's ability to read nature I used the SOLO-taxonomy (Biggs & Collis 1982).
The main findings were that taxonomy is not primarily a goal in itself but rather a starting point for a more sophisticated ecological understanding. The results indicate the importance of using concrete examples which can be related to when students describe complex processes and correlations in ecology. The deep knowledge of the morphology, adaptations and feeding strategies of the freshwater shrimp seem to help all students to discuss the whole ecosystem in the tray interviews. The autecological knowledge was regarded as the glue between taxonomy and higher order ecology. Two students with different learning strategies developed in two directions during the instruction. One of the students was focusing on the naming of the organisms and did not reach a higher level of *reading nature* according to SOLO. The other student was not so interested in the organisms but more on the systemic level. Knowing the names and autecology of a few recognized organisms helped her to relate them to abstract processes in the ecosystem and discuss the system. This student's ability to *read nature* reached the highest SOLO-level.

9.1.4. Paper IV

Reading Nature- Experienced teachers reflections on a teaching sequence in ecology.

In this study I explored experienced primary school teachers' views on teaching for *reading nature*. A group of 13 primary school teachers with at least fifteen years of teaching experience in primary school were selected. They all had an interest for school development but none of them had a specialisation in science. From the teaching sequence in paper III, where a year 3-4 class studied a river ecosystem from a bottom-up approach, a video film was made. This 40 minute film was edited by linking clips from the main activities both in and out-of-doors. Two weeks prior to the interviews each teacher received the film on a CD together with a questionnaire which they were asked to fill in and prepare to discuss during the individual interview. The questions were mainly dealing with the possibilities and obstacles they could see for implementing such a teaching sequence in the everyday primary schools. The other issue was about their view on the importance of the ability to *read nature* as a goal in ecology education.

The results indicate that a majority found the aim of *reading nature* good and promising but the largest obstacle for implementation was the lack of methodological knowledge among their colleague teachers. It was not mainly the lack of content knowledge but rather the lack of experience to perform good outdoor instruction. First hand experiences of nature involving many senses were considered most important for outdoor learning. "*it gives them episodes, positive episodes, which they can relate to a long time after the field work*" as one of the respondents said. Other findings were the importance of real nature to visit where the teachers believed that most schools in the municipality had access to nature. They also mentioned the importance of the teachers' ability to arouse enthusiasm for ecology among the students. Using a video film is laden with cautions regarding validity. The content of the film has of course been influenced by the researcher both in the design of the instruction but also in the editing of the film where I have highlighted what I see as important. On the other hand all the interviewees had the same film as a point of departure and the individual discussion is based only on this film. Their own experiences and interests will of course colour what they see in the film which is highly individual and an aspect difficult to avoid.

10. SUMMARY OF THE MAIN RESULTS

In the following text I will give an overview of the main results from the empirical data. This overview will not be discussed but rather presented in this chapter. The chapter finishes with a conclusion about the analytical tools. In the following chapter, on the other hand, I will discuss the findings in relation to prior research and with a critical stance towards the conclusions that can be drawn from this material.

In paper I student teachers were interviewed three times in order to find answers to the following research question:

- **How do student teachers develop their ability to *read nature* and what are their views on important aspects of their own learning?**

In this study I did pre- and post course interviews with the students in small groups outdoors. Hence, the "How" in the question only refers to what they said in these two interviews and not the process of learning itself. The interviews were dealing with three aspects of *reading nature;* a) organisms and abiotic factors i.e. the plants and animals together with non - biological factors influencing the ecosystem such as soil conditions or light conditions. b) processes and cycles in nature and c) the human influence on the ecosystem. Students were asked to relate the theory of these issues to the real world – the ecosystem. The pre- course interviews revealed limited ability to link ecological theory to the real objects in nature. Most of the students could describe the forest ecosystem by correctly naming the trees and some of the other plants and insects. They had greater difficulties in including the abiotic factors such as soil conditions or light conditions influencing the life in the ecosystem. As the table shows six of the seven groups learned to *read nature* on a compatible and elaborate level in this aspect. (Table 2). This means that they had generally correct names for the common organisms and they were able to relate to them by pointing them out or in other ways linking to the actual objects in nature.

Table 2. Summary of the bi-dimensional coding in paper I.

	Code					
	Organisms		Cycles		Human impact	
	Interview I	Interview II	Interview I	Interview II	Interview I	Interview II
Group 1	GS	CE	GN	GS	GS	GE
Group 2	GN	CS	GN	GS	GS	GS
Group 3	GS	CE	GS	CS	GS	GS
Group 4	GS	CE	IN	GS	GS	CE
Group 5	GS	CE	GN	GS	GN	GS
Group 6	CS	CE	GN	GS	GS	CE
Group 7	CS	CE	GS	CS	GS	CE

Note: Each of the codes expressed is bi-dimensional; that is, each code delineates a combined judgement of the level of compatibility and the level of elaboration of students ideas. First dimension: C, compatible — statements concur with expert propositions; G, generally sound with a few (minority) statements not agreeing with expert propositions; I, incompatible — statements disagree with propositions. Second dimension: E, elaborate — statements relate to the ecosystem in a complex and holistic way and have sufficient detail to show the thinking behind them; S, sketchy — only few details and logic given, essential details are missing and no holistic view is given; N, non-linked — tatements are not linked to the ecosystem, rather like school-book content presented out of context without correlation to the surrounding nature.

Linking abstract processes such as photosynthesis or cycles of matter to the structures in the ecosystem seemed difficult to do in both of the interviews. All groups gave a sketchy relationship between theory and the ecosystem showing that despite the correct description of the processes the linking was difficult to do. For an elaborate level they were for example expected to involve the plants and the green leaves in the discussion about photosynthesis. The forest where the interviews were conducted was clearly influenced by humans with introduced species and arrested succession by logging. In the first interview few students noticed this but in the second interview most of them described it in an elaborate way.

The third interview was metacognitive and focused on their learning. The students found it very interesting and also surprising to hear what they said before and after the course about the same forest. They were surprised mainly of how little they knew or at least could say in the pre-course interview. What they mentioned as most important for learning to *read nature* was the excursions. Taxonomy and autecology was new for many of them and considered very important: Many of them said they "*saw the world with new eyes*" when they recognised and knew something about the organisms. They said they had developed a scientific language which helped them to express their *reading of nature*. Field work and excursions to different habitats and with opportunities to discuss and investigate the ecology were considered most important to their development.

In the second study I was following secondary students along a designed teaching sequence finishing with a transfer interview in a new environment. The specific research question was:

- **How do secondary students develop their ability to *read nature* according to a top-down teaching approach and how can they transfer their knowledge to another ecosystem?**

Prior to instruction only one of the 15 students claimed to have heard of photosynthesis and no students recognised more than one or two species of plants or animals. Succession and human influence on the forest was not considered, they spoke as if the ecosystem was in a static stage. They often talked about the food chain principle where everything living is food for someone else but they had great difficulties relating this to the actual forest. The process of decomposition was often recognised as 'leaves turning to soil by worms'. In the post-course interviews the largest development was in the fields of taxonomy and linking functional groups to a whole. The model of a food pyramid was useful in helping the students to reason about causality in more than single steps in nature. Most students had a cyclical idea where plants turn into soil by decomposers and something in the soil is cycled. This something was for some energy and for others it was sugar or minerals. Some students referred to dynamics in the ecosystem with natural succession but human influence was not mentioned. Decomposition seems to be a linchpin concept helping the students to recognise the cyclical processes in ecosystems. Photosynthesis was described on a molecular level by nine of the students and they all related to plants as producers of food and oxygen.

The transfer interview was differently staged. Each student was taken to a pond. They were asked to describe the pond and compare it to the forest. The interviews together with video recorded field work by the pond constituted the transfer data. The analytical tool was the Structure- Behaviour- Function analysis Hmelo-Silver & Green-Pfeffer, 2004)

On a *structural* level a majority of students related the algae and reed to the plants in the forest like spruces and moss. They also recognised some of the animals by their morphology such as snails and water hog louse which are resembling the terrestrial equivalents. Seven students also discussed the abiotic factors such as water and air but also molecules such as carbon dioxide existing in both ecosystems.

On a *functional* level twelve students say that plants must produce oxygen and food in the pond as well as on land. They link the animals they see to functional groups such as herbivores and predators. The food pyramid as a model for a discussion about the distribution of functional groups was also discussed by a majority of students. All these three abilities are referred to as schemata helping the students to *read nature*.

On a *behavioural* level a majority of students discussed photosynthesis on a molecular level but five of the students confused the reaction. All fifteen students discussed cycles in the pond but six students thought it was energy and not matter being cycled.

In conclusion the students could transfer their recognition of organisms and the idea of plants as producers of food and oxygen. Other basic ideas or schemata transferred by the majority was the idea of how to recognise functional groups, the food pyramid as a model and the idea that there is a cyclicity of matter or energy in the ecosystem. Ideas of succession and the distinction between energy and matter was difficult to grasp for most students.

In the third study the specific research question was:

How do primary school students develop their ability to *read nature* according to a bottom-up teaching approach (starting with the individuals and end with the system)?

The student were interviewed three times using tray interviews where objects from the river was already collected. Students were asked to link these objects in as many ways as possible to explain the river as an ecosystem. The results can be divided into the five SOLO-levels. Initially the students knew very few organisms in the river and they had no experience from studying this ecosystem. All students were on a *prestructural* or *unistructural* level of *reading nature* and they referred to single step and trivial links between the objects from the river. No relevant statements on systemic level were mentioned. Teleological reasoning was common such as regarding the water as important for swimming in. Reasoning about the functions of organisms in relation to whole ecosystem functioning was largely absent.

Prior to the second interview they had studied the shrimp (*Gammarus pulex*) and its autecology and they had collected and named animals in different parts of the river. The majority could read nature on a *multistructural* level. The shrimp, its autecology and its relation to other organisms in the river was discussed by the majority in a relevant way. They also related the morphology of different organisms to their life in the river. On a systemic level the students linked the trophic groups as in a food chain but there was no relevant connection between abiotic and biotic factors. The deeper knowledge of one organism and the taxonomic knowledge of several animals helped the students to read the river.

After the second interview the students had studied sealed aquatic ecosystems and they had discussed photosynthesis on a functional level as well as the food pyramid with examples from the river. Students had first hand experiences of life cycles, of feeding preferences among animals and of organism adaptations to a life under water. In the third interview most students *read nature* on a relational level. This means that they could relate the organisms to their habitat. They could also relate the community of organisms to the model of a food pyramid. The flow of energy in the ecosystem is described by linking the sun with the plants and the consumers and decomposers. Cycling of matter is not discussed and the behavioural level of reading nature is not discussed.

In conclusion the autecological knowledge of the organisms seemed to help the students to link the taxonomy with the synecology and make it meaningful for the students to learn about the more abstract processes and relationships in the river. Generally there was a strong development towards a more sophisticated reading of the river as an ecosystem. The teaching design gave room for parallel development of students with different foci. One student with a particular interest for taxonomy and another student with a strong interest for the functioning of the ecosystem both found that their focus of interest was stimulated during instruction.

The fourth study deals with experienced primary school teachers views on *reading nature* as it is presented in a film from the teaching sequence in the third study. The research question was:

- **What are experienced teachers views on *reading nature* as a goal in ecology education and the critical aspects of learning to *read nature* according to the teaching sequence in the bottom-up study in the primary class?**

13 experienced primary school teachers discussed the content of a video film highlighting the teaching sequence. The most important factor influencing the learning on the film was the teacher, the real hands on experiences and the structure of the teaching sequence. A few teachers found it too challenging and difficult to do in a primary school class. Regarding the possibilities and problems for implementing it to the everyday school situation they claimed that knowledge and confidence of the teachers was the most significant hindering factor. Most of them said that the knowledge of the teaching method was more critical than the ecological content knowledge of the teacher. Other critical factors were the quality of the surrounding nature, the attitudes of the students and the curriculum and time table. The latter issues were considered more as opportunities than obstacles with these young students since they normally were enthusiastic and the time table rather flexible. The motivating reasons for implementing this teaching was the importance of giving the students first hand experiences, the chance to involve multiple senses, and finally, to give them episodes to remember and refer to when discussing ecology in the classroom. They gave strong support for including *reading nature* in the curriculum.

In table 3 the research questions posed in papers I-IV and the main findings are presented in a condensed format in order to provide an overview of the research.

Table 3. Summary of research questions and main findings

Research questions*	Main findings*
Paper I	
How do student teachers read nature before and after a course in ecology? What are the students views of important learning situations during the ecology course? In which ways do they see their own developed capability to read nature?	Generally they developed their ability to discern and describe organisms and abiotic factors more than they developed their ability to discern human impact in nature. They found linking processes in nature to the real ecosystem difficult. Excursions and field based discussions were regarded as most important. They developed a new way of seeing nature and a new language to describe it.
Paper II	
What are the characteristics of students' expressed Ecological understanding of the terrestrial ecosystem before and after instruction? To what extent can the students apply their understanding in order to read nature in the aquatic ecosystem after studying the ecology of a terrestrial ecosystem?	Initially they had a limited ability to read nature. After instruction they often recognised organisms and their functional roles. Food pyramid was a useful model. General ideas of processes such as cycling of matter and energy flow was difficult for most students to apply to the ecosystem. In the new environment they related to similar structures such as plants or certain groups of animals, they could discuss processes in nature in a general way. They used the model of food pyramid and the functional groups of organisms. Dynamic processes in ecosystem was difficult to relate to.
Paper III	
How does students' sophistication in and ability to Read nature develop through a bottom-up study of a river ecosystem?	The deeper knowledge of a few species and their autecology was linked to more complex understanding and reading of the river ecosystem. Abstract processes such as photosynthesis difficult to relate to.
Paper IV	
What are the views of experienced teachers Regarding: a) the concept reading nature? b) possibilities and drawbacks of including reading nature in the everyday school situation?	Strong support for the idea and concept but the systemic levels too advanced for young students. Fieldwork important and gives episodic memories helping future instruction. Affective components important. Lack of real nature and competence of teachers the major difficulties.

* Research questions and main findings in abbreviated form; for complete versions see corresponding papers.

11. DISCUSSION

In the introduction of this thesis I mentioned the three facets of science education according to Helldén et al. (2005). The first surface is facing disciplines such as “pedagogy and education”. The second is facing practical teaching and the third the content of the subjects. In the discussion I will combine the different parts and discuss my findings in the light of the three facets.
In the section about results I presented each paper and the specific research question linked to each study. In the discussion I will now return to the general research questions in chapter five and discuss them across the whole study. I start this discussion with the question of relevant levels of reading nature for the different age groups. This is followed by a discussion of the critical aspects of the ability to *read nature* and finally the importance of *reading nature* as a goal in education.

11.1. What is a relevant level of the ability to *read nature* for different ages of students?

In the earliest phase of this study I defined the concept *reading nature*. My experience was that students of all ages as well as adults had difficulties discerning the characteristic structures of different ecosystems. In particular the problem was to link the structures to the underlying mechanisms and conditions governing the appearance of the ecosystems. Basically it has to do with the natural history of the environment linked to a selection of ecological theories. Ecology is a very broad discipline and I have had to exclude large parts of its content. This does not mean that this is less important but that it simply does not fit with the *reading nature* concept. How can we tell whether a person *reads nature* or not? As with many competences it is not a question of either-or but rather a continuum (White & Gunstone 1992). Hence, the ability has to be defined according to a relevant criteria, in this case the student group and their prior instruction and experiences. The different student groups have had different instruction so we cannot compare the influence of instruction across the studies. What it is possible to do, though, is to see a development in the sophistication of their ability to *read nature* from a systems point of view. In the SOLO taxonomy this is expressed as from the concrete and unistructural towards more and more abstract and relational reasoning.

In my analysis of the developing sophistication of *reading nature* I was inspired by Assaraf & Orion (2005) which I have mentioned earlier when discussing systems thinking. Their study describes 12 year old students’ developing systems understanding in relation to a course about earth systems. Their main focus was on how the organisms, the geology and the meteorological processes together influence the system. Their presentation of how the students develop more and more sophisticated ways of linking the structures has influenced my analysis across the papers. I have constructed a table which illustrates the development from primitive to more advanced readers of nature according to a bottom-up approach towards systems thinking about the ecosystem.

The progression of reading nature among the students
In order to get a more holistic view of the development I have used three criteria to describe the character of the knowledge at each systems level.

Table 4. This table is modified from Assaraf & Orion (2005) in order to show the progression in reading nature I can see among the students.

Level	Content knowledge (Abilities) about ecosystems in reading nature.	T: taxonomy A: autecology S: synecology SY: systemic ecology	SBF-analysis Structure Behaviour Function	SOLO U: unistr. M: multistr. R: relational EA: extended abstract.	Reading nature for P: primary S: secondary T:teachers
1	Naming of biotic and abiotic parts.	**Taxonomy**	**Structure**	**Unistructural**	**P S T**
2	Generalisation of organisms' ecological functions in relation to their features.	**Taxonomy** **Autecology**	**Structure** **Function**	**Unistructural**	
3	Identifying processes that create relationships between parts. (E.g. shrimps eat leaves and release nutrients for plants.)	**Taxonomy** **Autecology**	**Structure** **Function**	**Multi-structural**	
4	Building up a framework of relationships. (E.g. food chains)	**Taxonomy** **Autecology** **Synecology**	**Structure** **Function**	**Relational**	▼ (P)
5	Making generalisations about relationships (E.g. saying that all food pyramids must start with a plant.)	**Taxonomy** **Autecology** **Synecology**	**Structure** **Function**	**Relational**	
6	Understand that some relationships can impact on other relationships. (E.g. Many shrimps can affect the number of plants in the river.)	**Taxonomy** **Autecology** **Synecology**	**Structure** **Behaviour** **Function**	**Relational**	
7	Understanding that many systems go in cycles, such as decomposition and that energy flows linearly.	**Taxonomy** **Autecology** **Synecology** **Systems ecol.**	**Structure** **Behaviour** **Function**	**Extended Abstract**	▼ (S)
8	Recognising that ecosystems can change over time, both naturally but also by the human impact. (E.g. students can predict the future of an ecosystem or explain its status today.)	**Taxonomy** **Autecology** **Synecology** **Systems ecol.**	**Structure** **Behaviour** **Function**	**Extended Abstract**	▼ (T)

Regarding stages in progression of understanding systems Assaraf & Orion (2005) have shown a progression from the lowest to the highest level according to the levels one to eight in table 4. In column one I have added the examples from *reading nature*.

The first column has to do with the systems level of *reading nature* where level one is the lowest level and hardly deals with systems thinking at all but it can be seen as a prerequisite for further development towards systems thinking. The eighth level is, as far as I have found, the highest level the students are able to reach in discussing the ecosystem.It should be read as a cumulative sequence where one level builds upon the other. This is not necessarily true but it is the ideal mode for developing systems understanding through bottom-up instruction.

In the second column I have linked the eight levels to the type of knowledge involved ranging from *taxonomy* through *autecology* and *synecology* to *systems ecology* according to my definitions of these notions earlier in the thesis (section 4.8).

In the third column I have related *reading nature* to the levels to the structure-behaviour and function analysis (Hmelo-Silver & Green-Pfeffer 2004). Structure has to do with naming the objects in nature. Function has to do with the function of an element in a given system. Behaviour is dealing with explaining the processes in nature.

The fourth column represents the SOLO-taxonomy. In paper III I used this taxonomy to describe the sophistication of the primary students' ability to read the river ecosystem. The levels in that paper were adjusted to the content of the instruction. Together with the sophistication I also added an aspect of correctness to my revised SOLO-levels in the paper. In this table on the other hand I have used the original idea behind SOLO-taxonomy. Since the eight levels are not defining what is right or wrong it is possible to relate them to a relevant SOLO-level from the original work by Biggs & Collis (1982). It starts with unistructural and the highest level is extended abstract.

In the fifth column the arrows indicate a rough estimate based on <u>my</u> data of the level of *reading nature* for the three groups in the papers. *P* represents primary school students. In this case the 10-11 year old students. *S* represents secondary school students. In this case the 13-14 year old student. *T* represents the student teachers in paper I. The majority of students in each age group reached the level indicated by the respective arrow. Each arrow is independent of the other and it is not possible to generalise across the age groups since each study was designed differently and the instruction prior to the post course data collection differed.

Level 1: Naming of biotic and abiotic parts
In the first level the main focus is on the discernment of the biodiversity and naming of common organisms or other structures such as soil type or bottom substrate. To exemplify this stage I refer to the second interview in paper III where the students described the shrimp and its morphology. They also collected other animals and identified them from the literature. This relates to the first goal in the Swedish biology curriculum for year five: "*naming of common plants and animals*"(Skolverket, 2007) Basically it is restricted to taxonomy and only the structural level of the SBF analysis is involved. In the SOLO taxonomy this is related to the unistructural level. The content knowledge is naming and recognition of species and the learning process involves competencies such as observation and discernment. The ability to know what to look for in order to tell the organisms apart is an important skill. At this stage it does not involve any systems thinking but the naming is a prerequisite for further discussion about ecology. I refer again to Linnéus' statement "without the names the knowledge of the things is worthless" (Linnéus, 1737). This stage was accomplished by all students after instruction. The student teachers had reached this stage prior to instruction. In my earlier discussions about natural history as a prerequisite for ecology in *reading nature* I refer to this stage as natural history.

Level 2: Generalisation of organisms' ecological functions in relation to their features.
This has to do with discerning the differences between organisms but also observation of how they act and how they are adapted to a life in the ecosystem. Characteristics such as the morphology and actions of the organisms can be linked to functional groups in the ecosystem. "*Ooh that one must be a predator. Yes it has big eyes and mouth and it moves fast. Yes it must be*"(Fredric in transfer interview, paper II p.79). This level involves taxonomy and autecology where structure and function are linked. Regarding SOLO taxonomy it is regarded as unistructural since only single characters need to be linked to the species and it does not

involve systems thinking. What it does is that it changes the focus from naming to adaptation and it is one step closer to a discussion about the ecosystem as a whole. This is an important part of natural history necessary for describing an ecosystem without explaining any processes.

Level 3: Identifying processes that create relationships between parts.
The focus is on the ability to link the organisms and abiotic parts to processes in nature. An example is the feeding relationships where the shrimps are feeding on dead leaves linking these together and realising that one cannot be exclusive of the other. This is an important step towards *reading nature* but it still involves very simplistic relationships. Single step links in food chains is an example. Structural elements such as the shrimp are linked to functions and it involves taxonomy and autecology. It is possible to reach this level with only the most common names of the organisms. This is what Hugh and several others of the secondary students (paper II) said in their pre- course interview "*it is worms that eat the plants and turn them to soil*" (Hugh in paper II p. 77). This knowledge is exemplified from several other studies on decomposition (e.g. Hogan & Fisherkeller, 1996). This level involves a discussion of functions in ecosystems. It involves taxonomy and autecology. In the SBF analysis it involves both the structural and functional aspects. It has to do with linking the organisms together in a relevant way but with few objects involved. Therefore it is regarded as a multistructural level. One third of the primary school students did not reach further than this level and it is also what is described in their curriculum as a relevant level.

- recognise and be able to name common plants, animals and other organisms in the local environment, as well as be familiar with their environmental requirements,
- be able to give examples of the life cycle of some plants and animals and their different growth processes (Skolverket 2007)

All of these parts of the curriculum fit under this second level which I refer to it as natural history.

Level 4: Building up a framework of relationships.
This is the first stage towards ecological reasoning and it is built on students' knowledge of the natural history of the animals and plants in the ecosystem together with models of food chains and cyclic processes in nature. Food chains can be organised based on the common organisms discussed in the earlier levels. Cyclic processes are also part of this where the most common is the decomposition when dead leaves turn to soil which the plants take up again. In the studies I have along with Grotzer & Bell Basca (2003) seen that students both in primary and secondary school have problems with relationships between organisms and they often describe them as single step and basically telling who eats who. Food chains are often described in biology books for compulsory school where the organisms involved are chosen since they are familiar to most students. In this case the organisms in the chains are chosen by the students themselves and the choice is based on their experiences. This I see as important for the relevance and motivation when we move towards more abstract reasoning. The importance of personal experience of the organisms appearing in the theoretical models is supported by Magro et al. (2001). The experienced teachers in paper IV also mentioned the importance of giving students first hand experiences and episodes which can be related to when exemplifying the theories. A synecological stance is now taken and this is added to the taxonomic and autecological level. This is an example of reasoning on a relational level according to SOLO.

Level 5: Generalisations about relationships
This level builds on the former levels but students can generalise their synecological ideas and often transfer them between contexts. An example of this is when Fredric in paper II said "*there must be most plants because they are the energy source for all*" (p.81). In the same vein they often said that there has to be light for all organisms to survive. These are examples of generalisations based on a systems insight or at least an idea why some basic elements in an ecosystem are needed. In the pre-course interviews the primary and secondary students claimed the importance for light or plants but they often came up with teleological reasoning. In the transfer interview most students said that there has to be light for the plants to make sugar and oxygen. This is an example of relevant generalisations across contexts.

Level 6: Understanding that some relationships can impact other relationships
This level is complex and can be regarded as metarelational where the students have to think laterally and consider direct and indirect effects in the ecosystem. Understanding the models of food webs and food pyramids are examples of this level. This level involves the synecology (the relationships between the organisms) but not systemic ecology which includes the abiotic factors. The level is reached only by a few of the primary school students. Most of the secondary students reason about this in a correct way when they build their sealed aquatic ecosystem in the transfer study "*Energy is lost along the way because they use the energy to move forward and eat and yes, it costs to do a lot of things and if it is going to last all the way up to the carnivores there has to be a lot of plant eaters or more animals will have to eat both plants and animals*" (Hugh paper II p. 89). The difficulties students have with thinking in several steps is not surprising in the light of Webb & Boltt (1990) who showed that students at upper secondary school often believe that a change in one population will only affect another population if the two are directly related. The student teachers did not discuss the food pyramid and its applications to the ecosystem. The secondary students on the other hand, who were introduced to the food pyramid in the forest, also discussed it in the aquatic ecosystem. The model seemed useful for the majority of secondary students in their transfer interview. With the primary school students this is not so easy to tell since only a few of them made a direct connection to the model in their interviews. In the third tray interview the majority discussed the food chain and added the biomass aspect as a fact.

Level 7: Understanding that many systems go in cycles. This has to do with understanding the important cycles of matter in nature and relating them to the structures. Research has shown the difficulties in grasping the abstract cycling of carbon involving photosynthesis and respiration. The understanding on a molecular level is referred to the behavioural level in the SBF-coding scheme. The interviews showed that the understanding of these abstract processes was not enhanced by the staging in the outdoor context. The student teachers could discuss the processes as a straightforward chemical reaction but they did not spontaneously link it to the environment. With the secondary students the construction of sealed ecosystems seem to trigger the discussion about this linking. This is what Carlsson (1999) and Helldén (2004) also found in their discussion of the cycles in sealed ecosystems. With the sealed ecosystem the intuitive ideas of a constant refill of oxygen and water are challenged. In an open ecosystem these challenges are not obvious and does not trigger the confusion (Andersson, 1990). On the other hand a question in the forest of "How do things work in this ecosystem?" allows the debate about cycles to surface. For the youngest this simply means that the soil is cycled. The secondary students often described the process as part of the carbon cycle. Discussing the processes on a molecular level means that the behavioural level in the SBF-coding is involved. Bringing the students out in the ecosystems does not enhance their ability to discuss these processes but the processes are still a part of systems thinking in ecology and of the ability to *read nature*. This stage involves taxonomy and autecology but also synecology and since it involves the abiotic factors and chemical processes in the system it also refers to the systemic aspects of the ecosystem. It has to do with generalising the processes across ecosystems and therefore it is considered to be on an extended abstract level according to SOLO. Some of the secondary students discuss this when they construct their sealed aquatic ecosystem and say that carbon has to be cycled between the plants and the animals (paper II p. 92).

Level 8: Recognising that ecosystems can change over time, both naturally but also by human influence. This stage demands a historical perspective and an understanding of succession which my study has shown not to be an intuitive idea. In the primary class the students did not reflect on this aspect at all. The secondary students were studying succession and human influence in a forest during one of the lessons. They were also asked to predict the future appearance of the ecosystem both in the forest and by the pond (paper II). In the first forest interview the common idea was that nature is static. In the second they had learned that this ecosystem changed over time but when they were asked to predict the future of the pond in the transfer interview they were all back on their original ideas of a static ecosystem. The student teachers though discussed succession and the gradual change in the forest. They also recognised the human influence by logging or indirectly by discussing the effects of air pollution which they could determine from the lichens on the tree trunks. This level involves the Structure-Behaviour and-Function levels and it includes systemic thinking where the students have to reason about multiple factors including time resulting in gradual or rapid changes in an ecosystem. A reader of nature should be able to recognise the human influence in an ecosystem and see that some ecosystems are highly influenced and often with a loss of biodiversity as a result. This ability is complex and generalisable between ecosystems and considered an extended abstract SOLO-level.

The Natural historians and the Ecologists way of *reading nature*.

In table 3 there is a clear progression from the concrete organismic level to a level including the more abstract processes not easily observed in nature. The teaching sequence for the youngest students had this bottom-up design. They were familiar with the organisms. They also knew much about the ecology of the shrimp but also of many other organisms they had found and studied in the river. In the interviews they often discussed how the organisms were related according to a food chain or sometimes to the food pyramid involving some of the synecological thinking. Very few of them could relate to the processes in nature such as the flow of energy or the cycling of matter. This involves higher order cognitive skills which have to do with ideas of transformation of matter and energy involving ideas of atoms and molecules.

A majority of these students reached the fourth level of *reading nature*. I would define this as the *natural historian's way of reading nature*. Many adults who enjoy being out in nature would probably agree with this as their way of *reading nature* too. It has to do with recognition of the relevant things to see and knowing why they are there. It has to do with feeling at home in nature as one of the teachers said (paper IV p.76). I keep coming back to Linnéus but I see him as an excellent example of a natural historian. The type of knowledge he symbolises deals with having names for organisms and linking the autecology to the relationships between organisms and to their habitat. This is a highly relevant part of *reading nature* both today and in the 18^{th} century. This is also the level demanded in the curriculum for the youngest students.

Some of the secondary students and all of the student teachers reached what I would call an *ecologists way of reading nature*. This includes all the natural history mentioned previously but it also includes the abstract and not visible parts of *reading nature*. This has to do with processes on a molecular level. It refers to the behavioural level of the processes according to the SBF-coding scheme. The non-intuitive ideas of dynamics in ecosystems were difficult to grasp. Most of the student teachers could *read nature* on the eighth level after the ecology course but they found it difficult to relate biochemical processes to real objects in nature. The problem in schools today as I see it is that we often do not reach the natural historian's way of *reading nature* and when there is no link to the ecologists' way of reading nature the relevance of understanding the abstract processes is reduced and isolated from the real ecosystems.

11.2. What are the critical aspects for learning to *read nature*?

In this study there are several aspects that I have found by analysing the data on students' *reading nature.* These aspects mainly refer to the content knowledge and scientific knowledge. There are on the other hand also substantial data from students own views about important aspects for learning. I will start this discussion by referring to what the student teachers and the teachers say about the critical aspects for learning.

The outdoor context

This is naturally a prerequisite for learning to *read nature.* Fisher claims that 'the laboratory for the study of life sciences is the 'field'; anywhere else the experience becomes second-hand, out of context and relatively meaningless' (Fisher, 2001). I agree with this but in my studies much of the learning takes place in the preparation for and the work after the field studies as well. Why can we not study ecology indoors and transfer the knowledge to the authentic natural world out-of-doors? According to transfer studies and according to the theory of variation there have to be certain basic similarities between the situations for transfer to be possible (Marton, 2006). In my study certain abilities experienced and learned in one ecosystem can be transferred. Recognising patterns in nature and discerning similarities and sameness between objects is the key to transfer (Marton, 2006). Theories without anchorage in real experiences have failed to transfer in several studies (Lave 1988). Learning to *read nature* and to transfer the ability requires field studies and a variety of examples illustrating the same phenomenon.

Excursions and field work.

In other studies excursions are considered to be the most important part of ecology education but also the most difficult to teach (e.g. Hale 1993). The student teachers regarded the excursions as the most important learning situations during their ecology course. The first hand experiences and opportunity to discuss with peers or with the teacher about ecology in the field was of key importance to the student teachers. The experienced teachers also stress this importance. "*You must have walked in the moss to be able to understand the forest*"(Paper IV p. 76). Even if this statement is not backed up by empirical data it is a conviction held by the majority of the teachers. The episodes and involvement of many senses is claimed to be of great importance. Poor planning and instruction will lead to poor results. In conclusion fieldwork is necessary but it needs to be well performed and planned.

Developing a scientific language- Ecologish.

*"I used to know something about nature in Swedish but now I know a lot more and I speak Ecologish, a better and more precise language"(Patric in Paper I p.*1241).

In the above statement, there is an awareness of a developed language- nicknamed Ecologish, facilitating student´ discussions about nature. Student teachers reflected on their new language where they expressed themselves more precisely and with much more certainty in the second interview. Lemke (1990) claims that language not only should be regarded as a passive medium through which our thoughts are expressed but rather as actively forming our ability to observe, describe and compare. Learning science means learning to talk science and to participate in a communicative practice. Each scientific discipline has its own semantics and learning to express relationships between its concepts is of key importance in mastering a discipline. The literature on the semantics of science is extensive but the analyses are usually based on the researchers' view and not, as in this case, the students' own views.

One way of describing the relationship between "Ecologish" and a natural language such as English is in terms of the linguistic notion of *register.* Halliday (1978) specifies this notion as "a set of meanings that is appropriate to a particular function of a language, together with the words and structures which express these meanings" (p. 65). The expression of ecological ideas and meanings, is when an ecological register will develop. The language "Ecologish" also includes the meanings and ideas behind the concepts i.e their functions. Handling the registers of "ecologish" is an important component in the ability of *reading nature*.

Seeing autecology as the glue between taxonomy and systems thinking
I will now discuss the critical aspects of content knowledge where we should bear in mind the levels of taxonomy through to systems ecology presented in several places in this thesis. I will discuss them from an empirical point of view and in relation to relevant research.
Without knowing the names it is difficult to *read nature*. There are several recent papers expressing great concern about the decline in taxonomic knowledge (e.g. Bebbington 2005, Lyal, 2005). The basic idea behind their concern is that species knowledge and taxonomy in itself is an important goal. In the Swedish curriculum this is expressed as students by the end of year five should "*be able to name the common plants and animals in the nearby nature*". My study has shown that taxonomy is important for introducing the ecosystem. Collecting and identifying the occurring plants and animals can be an interesting activity in itself. As Barker & Slingsby (1998) writes; "*Children have an innate tendency to want to name things, to appreciate differences and to classify*" (p. 480.). Peter in paper III was an example of this. He was fascinated by the different life forms and learned their names with enthusiasm. Several of the student teachers expressed a fascination for how their newly gained taxonomic knowledge influenced their view of nature. Edith said in her metacognitive interview (paper I): "*we see nature with new eyes now*". In the same paper another student teacher reflected on the naming of organisms as a new language which refers back to the section above about the Ecologish. He said: "*Species knowledge is like a language. You need to have the right names to be able to communicate*". (Jonathan, paper I p. 1244).

With *reading nature* as a goal in biology education taxonomy gets a more elevated position. Naming the common organisms in the ecosystem is the first step and a necessary point of departure for linking higher order learning skills. The skills of identification learnt along the way are a means to an end rather than an end in themselves. As I see it the naming is part of the language of Ecologish (paper I). In school biology the naming often relates to 'morphospecies' (recognisable taxonomic units), such as snails or wood lice (in the thesis they are all described as species). Generalisations like this, have to be carefully made since morphologically and taxonomically close species can have very different autecology. If they are chosen with care I see these generalisations as a fruitful way forward, avoiding getting tangled in too much with problems of classification.

In learning to *read nature* the idea is that the taxonomy can be linked to systems thinking via the autecology of the species. In paper III students learned about the function of freshwater shrimps and water louse as decomposers by experimenting on their food preferences. This is an example of how taxonomy is linked to autecology. From this point of departure the students are prepared to discuss models of food pyramids or cycling of matter. It is the link to higher order learning skills dealing with synecology and systems thinking. As I see it autecological knowledge is critical for *reading nature* on a higher level.

Food pyramid - a model which can be transferred

The interrelatedness in ecosystems is not easy to grasp (Grotzer & Bell Basca, 2003) The model of food chains is introduced in most biology books for primary school. Despite the simplicity of this model Munson (1994) has shown that many students in secondary school and above see that the species at the top of the food-chain have advantages such as gaining most energy or being able to feed on all levels lower on the food chain. Many students also see it as simply a model of who eats who with little link to the real ecosystem. There are also the problems with causality where students tend to think in single steps. They reason locally and miss the larger picture, the systems level interactions and the indirect causality (Penner 2000; Grotzer & Bell Basca, 2003). Paper II describes a study of the gold crest eating a large number of invertebrates in order to compensate for the energy loss on cold days. This involves the aspect of biomass and energy budget of populations. The food pyramid was found to be a useful model for discussing these aspects. It guides the students to find out about which trophic level the organisms belong to. It also gives a hint on the distribution of the different groups where the biomass of the producers has to be dominant. In the transfer interview (paper II) the students could transfer the idea of functional groups and their general features such as fast movement and large eyes and mouth parts for predators. This is a critical aspect for *reading nature* together with the ideas of trophic relations, biomass and energetics of the ecosystem which are all implied in the food-pyramid model. This model I regard as a form of schema which the student can transfer between ecosystems helping the student to *read nature* in different ecosystems. At a fundamental level, all students need to understand that the purpose of model is to simplify and clarify more complex systems. The collection of organisms from sampling may not fit with the food-pyramid model. If the model is a schema for the student this would challenge the ideas and may possibly lead to ecological discussions.

Abstract processes and reading nature

In the bottom-up approach the study of the structure and function of the organisms in the ecosystem is followed by more abstract representations of ecosystem functioning. This has to do with the mechanisms influencing the whole ecosystem, the biochemical processes and the flow of energy involving both biotic and abiotic structures. Extensive literature suggests that students do not have a good grasp of energy flow or of the dynamics and structure of ecosystems (Adeniyi, 1985; Gallegos et al, 1994; Hogan & Fisherkeller 1996; Leach, Driver, Scott & Wood-Robinson, 1996; Grotzer & Bell Basca 2003). In this project we are not only interested in how they understand the isolated phenomena but more in their ability to relate the phenomena in the natural context and to link the parts to a whole i.e. to use systems thinking.

Photosynthesis and reading nature

Prior to instruction the students in the primary and secondary classes regarded plants simply as hiding places for animals and some of the secondary students also saw them as a food source. After instruction the majority in both groups said that plants produce oxygen for us to breathe and food for the plant eaters. It seems as if the interest of the majority of students was lost when we introduced photosynthesis as a chemical equation. It is also interesting to notice that the student teachers who were familiar with the biochemistry of photosynthesis (at least they said so and they had recently discussed it in a biochemistry course) did not link it to the ecosystem in neither of the two interviews. It does not seem a relevant connection to make spontaneously. Numerous studies have been conducted on the deeper understanding and consequences of photosynthesis. Helldén (1992, 1995, 2004) presents in a longitudinal study from school year two up to upper secondary school on how ideas regarding transformation of matter constructed early and often out of school were stabile over the years. Bergqvist (1985) asked a group of student teachers about a sealed ecosystem with soil and plants. He found that the majority of students reasoned in a way which lacked the holistic view of the cycles in the system although they mentioned the relevant details such as oxygen, light, decomposition and photosynthesis in a correct way. He called this serialistic reasoning. In a study on student teachers ecological understanding Carlsson (2002) found that the key to understanding photosynthesis, cycles of matter and energy in relation to ecosystems was to realise the idea of transformation i.e. the insight that in chemical reactions atoms are reorganising. Maybe the student teachers did not see the basic idea of transformation as relevant or at all. Carlsson's idea is highly relevant for *reading nature* on a systemic level but below that and for the compulsory school students the most important thing is to realise the huge impact of plants as 'producers of food and oxygen and requiring carbon dioxide and water plus solar energy to grow' and that this process is the motor in any common ecosystem.

Cycling of matter as part of reading nature

Decomposition may be a better point of departure than photosynthesis for discussing the systemic level. Understanding decomposition in terms of organisms using dead organic matter as a food source and releasing the nutrients to the system was the only systemic reasoning for some of the students. This is echoed by Hogan & Fisherkeller's (1996) and Leach et al.'s (1996) findings that students readily integrated knowledge of microbes as decomposers in ecosystems but despite relevant instruction they did not discuss photosynthesis in the ways they were exposed to in science class. A reason for this may be that photosynthesis is too abstract whereas decomposition is more compatible with their notions of food. A critical aspect for the younger students is to realise the cycling of matter in nature. Decomposition with the relevant and often abundant decomposers in an ecosystem is easily tested through experimentation. Already the insight that matter is cycled is an important step towards a discussion about cycling in ecosystems. If we return to Linnéus again we can see that already in 1746 when he visited a graveyard he expressed the idea of cycling of matter, though in a somewhat macabre way:

"*While taking the top-soil from the graveyard, I take the stuff which constitutes and has been transformed by humans into humans; I carry it into my cabbage-garden and sow cabbage plants therein; I get heads of cabbage instead of head of humans, but if I cook these heads and give them to people. They will once more be transformed into heads of humans and other parts, etc., Thus we will eat our dead, and this will do us good*". (Linneus, 1747).

If I had interviewed Linnéus about what it was that was recycled in the plants he might have hesitated in the same way as the secondary students who did not know if it was energy or matter or soil that was cycled. For nearly half of the secondary students the energy package (glucose) was used as a metaphor for energy. It symbolised the product from the plants and the food for all consumers. In the transfer interview the majority of students reasoned about the cycle of matter in the lake in the same way as in the forest. They had difficulties discriminating what it is that is being cycled. Initially it was the nutrients that cycled but after instruction several of them were confusing energy with matter. This difficulty is supported by other studies (Watson & Dillon 1996, Leach et al.1996, Carlsson 2002) showing that ideas of consumption of energy are commonly held and the transformation of matter is not commonly understood. This difficult educational issue will be discussed further in the section on implications for learning and teaching.

11.3. How relevant is *reading nature* as a goal in science education?

Ecology, with its roots in natural history, has evolved into a broad field dealing with scientific studies of the interactions determining the distribution and abundance of organisms. To decide whether *reading nature* is relevant it has to be related to the formal goals in education and as I have illustrated earlier, ecology is a large part of biology education in our compulsory schooling in Sweden. The following sentences are taken from the curriculum and have direct bearings on *reading nature*:

By the end of year 5 students should:

- **recognise and name common plants and animals in the nearby environment and be familiar with their demands for life.**
- **be able to give examples of life cycles for some common plants and animals and their developmental stages.**

By the end of year 9 students should also:

- **Have knowledge about some of earth's ecosystems and of how organism interactions can be described in ecological terminology.**
- **Have knowledge of photosynthesis and respiration and the importance of water for life on earth.**
- **Be able to give examples of cycles in nature and of environmental challenges to the ecosystems.**
- **Have knowledge about the importance of biodiversity.**

From the table of *reading nature* from a systems approach (table 3) all these curricular goals are included. The unique thing about *reading nature* is not the content but the contextuality saying that you need to be able to relate these curricular goals to the authentic ecosystem. According to the teachers in paper IV this authenticity adds other aspects than pure content understanding. Affective aspects are developed through first hand experience with nature. In my study I find support for this when the student teachers in paper I express fascination for the biodiversity they have learned to appreciate through field studies. The importance of studying the organisms outdoors is also strongly emphasised by several of the primary school teachers in paper IV. One of the teachers said: "*I believe it is very important to be both indoors and outdoors for the understanding and for the feeling. You need first hand experiences. To touch it, to hold it and listen to it and feel it. Otherwise I´m here and nature is out there. If you have been out and tried this you can compare and you have references when you come out in different types of nature*."(p.75)

What the teacher added was the aspect of a feeling for nature which is embedded in the learning process where motivation is a crucial factor for learning. This is also expressed by another teacher in paper IV in the following way regarding the importance of giving students memorable episodes during instruction:"*You remember an experience more than just words. You get it home by experiencing it in reality. You need to know how it smells and feels in the forest before you talk about it. You need to be at home but it doesn't say anywhere in the curriculum even though we know that this is of key importance for this learning" (p.* 76*)*

This importance of giving the students memorable and meaningful experiences which anchor in the long term memory structures is stressed by Mackenzie & White (1982). My data shows that across the age groups the fascination for the organism is stressed as important for the development of motivation for learning. This is why the bottom-up design, starting with the organisms, is important for education for *reading nature* irrespective of age group. This is the natural way forward and what makes ecology exciting, rather than an endless list of things to be learned about organisms, is that it studies a living working system.

Since human beings have an important impact, directly or indirectly, on this system, the line between ecology and topics such as environmental education and education for sustainable development is hard to draw as ecology is a natural part of these topics. Over the last decades there has been a shift of focus in environmental studies away from ecology and closer to the social sciences (Palmer, 1998). I welcome this shift but I also want to stress the necessity of ecological understanding when dealing with environmental issues. As Slingsby and Barker (2003), put it "*the contribution of the biology teacher to education for, in and about the environment is of course to provide a scientific perspective but one that goes beyond providing factual information*". In *reading nature* these three aspects are very important. If I continue with a little bit of an historical review of how environmental education has developed it is obvious that the buzz words now are education for sustainable development and the goal is "action competence". Education for sustainable development is an emergent but dynamic concept that encompasses a new vision of education that seeks to empower people of all ages to assume responsibility for creating a sustainable future (Wickenberg, 2004).

It is grounded in four interdependent principles: 1)Biophysical systems that provide life support for all life. 2)Economic systems that provide the life support systems for people. 3) Social systems that provide ways for people to live together and finally 4) Population systems through which power is exercised to make decisions about the way social and economic systems use the biophysical environment.

The years 2005 – 2015 are proclaimed to be the decade for education for sustainable development and as I see it *reading nature* is an important part of raising a concern about the ecosystems and their importance as life-support systems. Without the recognition of ecosystems which are natural as opposed to disturbed and which have a rich biodiversity as opposed to impoverished is part of *reading nature*. This type of knowledge as I see it is highly dependent on hands-on experiences from field studies of ecosystems. It is also dependent on the focus described in the sequence towards systems understanding from a bottom-up perspective (table 3). To develop this awareness you need a knowledgeable teacher and a structure and goal in the education. Being able to *read nature* adds the perspective of concern for something you have personal experience of. This is different, as I see it, from something you have only second hand information about such as book knowledge. This view is strongly supported by the experienced teachers in paper IV. Adding the affective component to an intellectual conviction of the importance of functional biophysical systems could boost our action competence.

12. METHODOLOGICAL ISSUES

12.1. The implications of my analytical tools

My study is part of science education research which is a social science, and it is grounded in empirical data which has been observed from a chosen perspective and analysed from a specific theoretical base. I have conducted four separate case studies concerning the same overarching issue- *reading nature*. The aim is to contribute to the awareness of how the ability to read nature can develop and of the critical aspects for learning to read nature. The claims for these are to be based on conclusions from valid and reliable information collected in an ethical manner.

Reliability

Reliability refers to the extent to which one's findings can be replicated. Merriam (1988) claims that "Reliability in a research design is based on the assumption that there is a single reality which if studied repeatedly will give the same results" but that "reliability is problematic in the social sciences as a whole, simply because human behaviour is never static" (p. 170). Since the term reliability in the traditional sense seems to be something of a misfit when applied to my kind of study I would like to refer to Lincoln and Guba (1985, p. 288) who suggest that in this type of studies reliability should be seen more as an issue of 'dependability' or 'consistency' of the results obtained from the data. That is, instead of focussing on replicability, they focus on the outsider's impression of the interpretations and results as grounded in the data and interpretations to be consistent. An example where cautions of dependability has been taken is from paper IV where the video film discussed with the teachers also is available on internet and the questions for the teachers are presented in the paper. In general I have described the processes both of instruction where the teaching design has been outlined but also the collection of data together with the analytical tools. Another issue which adds to the dependability is to make the investigator's position clear. In chapter 4 I have explained the assumptions and theory behind the study where the concept *reading nature* has been defined. The participants and how they were chosen have been described (in 6.9.). Important to say is that the selection of people was purposeful rather than random. In research projects like this it is important to build the cooperation on a professional basis between the teacher and the researcher. To carry out this sort of research you need teachers who are supportive and willing to adapt to the specific situation involved in case studies like mine. In my research I was not familiar with the students and according to the teachers their classes were not extreme in any sense. The social context from which the data has been collected is also important for dependability. The outdoor context both for instruction and for collection of data is special for my study and needs to be taken into consideration for the dependability. I see this as critical since it is difficult to describe this in enough detail in order to reach a high dependability level.
Another aspect which Kvale (1996) claims as important for reliability in studies like mine is the interviewers experience and skills. Prior to this study I had carried out several interview studies with teachers and students but despite this I notice an improving skill of interviewing represented by for example more patience and fewer interruptions by me in the later interviews.

The personal influence in a case study like mine is obvious and has a strong impact on its dependability as well as its validity. All through the thesis my own prior experiences and presuppositions are colouring the study. The considerations taken are filtered through my experience as a biology teacher, as an ecologist and as a researcher. The process I have been through to produce the competencies of reading nature presented in the thesis has for example involved a selection of ecological content knowledge where some parts of my understanding as an ecologist has nothing to do with reading nature at all. These aspect of subjectivity have to be considered as well as its influences on the dependability but also on the validity of the study.

Validity

What sort of things should then be questioned in a validation? As Carlsson (1999) writes: simply *everything* which might influence the findings of the study, e.g. *what* is being investigated, *why*, *when*, *where*, and *who* are involved. Thus, to validate is to focus on the credibility of the findings.

Some aspects of validation have already been addressed, the *what* and the *why* aspects related to the object of research has to do with the relevance of *reading nature* as a concept and why it is an important ability. The choice of focus is, of course, based on my personal interest in the issue. In an early phase of my doctoral studies I discussed with several teachers, colleagues and other researchers both within and outside Sweden about its relevance and content and I found strong support for this research. The fact that four articles and five conference presentations in international refereed situations are accepted supports the relevance of my research focus. I have in paper I and paper IV also discussed the relevance of the concept with student teachers and with experienced teachers where their support is strengthening the validity of the claim that *reading nature* is an important competence.

When you collect and analyse data this process consists of three parts: the description, the analysis and the interpretation (Wolcott, 1994). Each of these parts involves considerations and choices from the researcher which colours the outcome of the whole research.

Description and descriptive validity

The first part, the *description*, addresses the question "what is going on here?" and refers to how the data is collected and how well the description matches what actually happened. This study takes data mainly from interviews. All interviews and the collective field assignments in paper II when they construct sealed ecosystems in groups, was been tape recorded or video filmed. Verbatim transcripts are made from the audio tapes. I was present when all recording was undertaken. Students in paper II also made concept maps. After I analysed them they were discussed together with the student in order to straighten out uncertainties in my interpretation of them. The tray interviews in paper III was analysed while watching the interviews on video. Transcribing the material was difficult since they were constantly pointing at objects and referring to them without explicitly saying what they were. I found it effective to interpret the interviews directly as a concept map where the objects on the tray were the concepts and the linking words was based on their description and discussion.

The second part, the transformation of data, has to do with *analysis*. It addresses the identification of essential features and the systematic description of interrelationships among them. Simply "How things work". Again I have to consider my role as researcher and my choice of what is relevant data and what is not. In my papers I have published several quotes from the students. The transcribed data was analysed separately by me and my supervisor. Our interpretations were negotiated until consensus was reached. This process has been time consuming but important for the reliability of the findings. The categories in the papers are grounded in the data but often earlier research regarding the same content knowledge has influenced the number of categories and their main content such as "flow of energy". In paper II I refer to several different sources of data dealing with the same knowledge i.e.

concept maps, interviews and recorded cooperative fieldwork which together result in the categorisation of the individual students. If the outcome of this all point in the same direction, the validity is regarded high (Larsson 1993 p.38). The different sources I regard as complementary and often they support each other resulting in a more complex disclosure of *reading nature*.

I have basically selected three different analytical tools which I have slightly revised to fit my specific purposes. I will briefly discuss the advantages and drawbacks of each of these.

The revised Bi-dimensional coding scheme (Hogan & Fisherkeller, 1996) was chosen to help me to analyse ecological understanding on the one hand and the ability to link it to the real world objects on the other. These two qualities taken together give an idea of their ability to *read nature*. This study was a sort of pilot study helping me to see what the students found difficult to discuss in the field and what level of *reading nature* they reached after a general university course in ecology. The results influenced the future design of the research and the teaching sequences. When I wanted to look more closely into the sophistication of students' ability to *read nature* I used the SOLO- taxonomy (Biggs & Collis, 1982). I had some previous experience of this and I assumed that the developing ecological understanding in relation to a bottom-up sequence could be evaluated by this taxonomy. In the original version there is a direct relation between sophistication of an explanation and a higher level of understanding. For my purposes I wanted to add a correctness aspect since some ecological phenomena such as decomposition can be explained in a sophisticated way but contradictory to the scientific view. This means that I constructed a correctness aspect to the five original SOLO-levels. These levels were therefore partly grounded in my own data. There is an underlying epistemology here that knowledge is constructed with more and more sophistication and more and more complex relations between its parts. This idea is in line with human constructivism and the design of the teaching sequence.

In the transfer study I moved the students to a new environment and challenged their ecological understanding in order to see what they could transfer from the first to the second ecosystem. In the first ecosystem I had interviewed each student and structured the data according to different aspects of *reading nature* such as species knowledge or understanding of cycles in the ecosystem. In the transfer interview I was worried that they would repeat what they had said earlier in the two forest interviews. I therefore used a new interview format where I asked them to compare the ecosystems. To analyse the interviews I used the Structure-Behaviour- Function analysis (Hmelo- Silver & Green-Pfeffer 2004) This tool is helpful when the goal is to analyse how advanced their reasoning about the new environment is where transfer on a structural level means that they can see similarities in structure which is regarded as less advanced than transfer of understanding on a functional and behavioural level.

The third part has to do with the *interpretation*: In this stage the questions "What does it all mean?" and "What is it that I want to tell?" are central. Now there is a larger generality claim than in the *description* and *analysis* parts and my data has to be related to existing theory. The quality of the whole study could be discussed in the light of its inner logic and of its generalisability (Larsson 1993 p. 39). Difficulties in generalising from small samples are sometimes stated as an objection against case studies. The case study approach is chosen because one wishes to understand the particular in depth, not because one wants to know what is generally true of the many (Merriam,1988). Choosing a collective case study as I have done is decided because '*it is believed that understanding them [the cases] will lead to better* *understanding, perhaps better theorizing, about a still larger collection of cases*' (Stake 1998 p. 437). My goal was to present a broad perspective of reading nature as a goal in science education. The notion *reading nature* is new and there is no prior research to relate to in this specific issue. This is why I found it important to, instead of repeating studies with the same age group, broaden the perspective and involve four different age groups dealing with the same phenomena. As I see it the more data I collect on the same issue and engage in persistently the more it adds to the credibility of what I can say in a general sense. This is not a triangulation in its strict sense but I see it as a credibility check where the data support each other around the chosen phenomena.

13. CONCLUSION AND IMPLICATIONS

As we have seen, *reading nature* is hierarchical in its structure. This implies a pattern of critical aspects added to each other in more and more complex ways of seeing the ecosystem. According to the theory of variation, the discernment of a particular aspect i.e. a critical aspect, is a prerequisite for understanding a phenomenon in a specific way. Experiencing a variation and a simultaneity in these particular aspects are prerequisites for discernment (Bowden & Marton, 1998). This should influence the design of the instruction.

The other theory is that of meaningful learning (Ausubel, 1968; Novak & Mintze 1998) where it is important to link new theory to what the learner already knows and to facilitate the subsumption of new aspects of knowledge. This is done by deliberate efforts to enabling them to see certain things in certain ways which are supposed to be effective in the specific ecosystem and to give them ideas of how to interpret what they see also when encountering new ecosystems. This is as I see it what teaching for reading nature is all about. To start the discussion of how this can be done I would first like to recapitulate the findings in general terms. *First* the study reveals in general terms and in relation to ecological literacy: "what is reading nature?" *Second*, how do different student groups develop the ability to read nature? *Third* what are their views of critical aspects in the learning for reading nature? *Finally* the findings of the study point out some difficulties in developing this ability as well as possibilities of how these may be overcome. Altogether these descriptions point at the "what" aspect of teaching.

If we look at this more specifically and relate it to some of the critical aspects for *reading nature* In the concept reading nature there is a dialectic relation between a natural history part or experience-based part on the one hand and a more abstract or scientific part on the other. This means that reading nature has to be developed by combining the affective and experiental with the abstract aspects. In a perspective of the theory of variation the two aspects have to be present simultaneously and a oscillation between these two aspects is necessary. If we start from the lowest level of reading nature the organisms have to be focussed early. This necessitates a good idea of how to interpret what you see in nature. You need to be able to discern the relevant objects from the irrelevant ones. The natural step forward after having named the species is to find out more about them. In paper III the shrimp (Gammarus pulex) was carefully chosen. It has an interesting biology and it is dominating in this river. It is easy to find information about it but it is also a species which is not very well known to people in general. Looking at the biodiversity unrestrictedly is important but for further discussions about synecology it may be effective to guide the students to select a limited number of species. The idea of the food pyramid together with the ability to relate the features of the organisms to their functional group were often useful knowledge in the transfer interview when student read the new environment (paper II). These are all examples of the experience based parts. The instruction for this will involve field studies and close observations and investigations of the real objects. If we return to the curriculum emphases involved (Roberts 1988) it has to do with *everyday coping*, *scientific skill* development and *solid foundation* for further studies. I would also like to include my added emphases from chapter 3.4.10. namely the *appreciation and fascination for nature*, *the language of ecology* and the *outdoor experience*. These are all important aspects involved in the learning.

If we move to the more "scientific aspects" we take a step into the abstract part of reading nature involving the molecules and the concept of energy. Regarding curriculum emphases this level includes the ideas of carbon cycling and environmental issues linking it also to the *science, technology and decisions* emphase. The biochemistry of photosynthesis confused the primary and secondary students. Knowing that plants produce food and oxygen for all other organisms is an important knowledge but the move to molecules was not very effective for most of these students. Is the alternative to delay the biochemistry instruction to upper secondary school, when even then few students achieve a clear understanding of its principles (Andersson 2000, Leach et al. 1996)? An alternative is to build a foundation for later understanding on the concept decomposition which students have some intuitive ideas about which are compatible with expert propositions. All students who mention cycles exemplify it by this process but the object which is cycled is either soil (paper I) or nutrients or energy (paper II) This requires acknowledging that concepts such as energy and matter, serving as core understandings of modern ecologists may not be as foundational and generative for children. In our top-down approach (paper II) we started with photosynthesis and respiration on a molecular level. Starting with the more intuitive concept of decomposition might be better and can provide a bridge to more abstract nutrient cycling concepts. Focusing on existing macroscopic, descriptive and functional views of food, eating and excretion (Barker & Carr, 1989) may provide a bridge to molecular representations of ecological processes.this is supported by Hogan and Fisherkeller's (1996) findings about primary school students understanding of decomposition.

My experience is that building sealed ecosystems designed by the students themselves has been a motivational task demanding their knowledge of what the organisms need to survive and "who eats who" in relation to the model of a food pyramid. The sealed ecosystem has also challenged their ideas of the cycles of matter and flow of energy through the ecosystem. Isolating a living system from everything except light often challenge students scientific presuppositions (Andersson 1990, Helldén 1992). In the bottom-up design with the primary school students the atoms were introduced as LEGO pieces and the process of photosynthesis and respiration/decomposition was described. A few of the students, such as Anna (paper III) did discuss the role of the plants as producers of oxygen and food by taking in carbon dioxide and water. She also mentioned the problems with too much dead leaves in the sealed ecosystem resulting in too many bacteria eating the leaves and consuming all the oxygen (see Anna's concept map in figure 5 in paper III) . In her case the decomposition was again the intuitive process which she could refer to. As I see it she probably did not reach a scientific level of *reading nature* but in line with what I suggested, decomposition can be a way of introducing the scientific aspects of reading nature. Having said that I want to stress that it is important to learn to *read nature* on an experience based level without introducing the scientific components of it too early. A deep knowledge of the natural history is an important goal in itself.

I would like to leave the discussion about the content knowledge and move to the implications regarding the outdoor context which is central in this thesis. To be able to learn to read nature you simply need outdoors experiences.

As I have noted earlier the key is not the outdoor context itself and it does not have to be the larger part of instruction but they have to be well planned and executed. The activities have opened up for learners with different interests and background. This was exemplified by the student teachers in their metacognitive interviews in paper I. For one of them it was the possibility to come out and see things in nature and not hear about them in a lecture (Thomas) and for the other it was the chance to discuss ecological theory in relation to the real nature with an experienced teacher (Cathy). Instruction for reading nature must include field work but it is not at all necessary to conduct all teaching outdoors. What many of the experienced teachers said was that well planned fieldwork will give the students positive memories of the episodes. These episodic memories are very useful to relate to in the classroom when the ecological theory can be more meaningful and relevant if they relate to an experience. The importance of fieldwork styles for long term memory structures was studied by Mackenzie and White (1982). The researchers found a positive correlation between fieldwork and learning in general but in particular they found that excursions or fieldwork which encouraged processing and produced strong linking of episodes with content knowledge improved students understanding in general but their long term retention of knowledge significantly. Narratives and personal relation to the scientific content is considered an important aspect of cognitive science and scientific literacy (Klein, 2006) and the concept reading nature certainly is an example of this. The prerequisite overshadowing all others, according to the majority of teachers in paper IV is the enthusiasm of the teacher.

14. FINAL REMARKS

Field courses for student teachers

For future teacher training I draw some conclusions from this work. The student teachers did indeed develop their ability to *read nature* during the ecology course. They mentioned the importance of species knowledge and of excursions to different habitats and to have the opportunity to discuss ecology in the field with more experienced peers or teachers. As Cathy mentioned she would not have dared to take her students out in nature before she took this course (paper I, p. 1249). They need to have the first hand experience. They also mentioned a frustration for their lack of competence to *read nature* indicating that they considered the ability to be important in their professional role. This frustration had to do with the problematic linking of biochemistry to the ecosystem. Bransford (1999) states that one dimension of acquiring greater competence appears to be the increased ability to segment the perceptual fields; that is learning how to see. Research on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognise meaningful patterns of information (Bransford, 1999 p. 36.) The change of perception seeing with new eyes is an example of this. As I see it we need to help the future teachers to know how to look, what to discern in nature but also help them to link what they see to some models of ecosystems functioning. The food pyramid is one of them. The decomposition is probably another. The biochemistry should be discussed, at least the effects of the processes on a molecular level in relation to the field.

Include reading nature as a goal in the curriculum for compulsory school!
Among the selected group of teachers there was a consensus about the importance of field based biology instruction. They were all trying to fulfil the curriculum demands but they said that such a focus on the autecology was not what they normally did. Naming of common organisms was conducted by them all. I think that a way forward encouraging the teachers to do more and hopefully better field studies would be to include the reading nature as it has been described in this thesis as a part of the biology curriculum for compulsory school.

Future research on the affective aspects and the link between abstract and concrete
In my thesis I have followed the different students along their development towards *readers of nature*. My focus has been on the content knowledge. The research has given rise to several ways forward towards developing better ideas of how ecological literacy can be achieved. It would for example be very interesting to analyse students' attitudes towards this fieldwork. In the video from paper III it is rich with examples of student attitudes towards the field activities and their varying affection for this type of instruction. It would be an interesting contribution to research if the affective and cognitive components involved in reading nature could be investigated more deeply. In several reports on the importance of field work it is mentioned that this type of activity may stimulate students who otherwise may be sidestepped by the content rich and abstract ecology in school (e.g. Rickinson et al. 2004). These students may reach far in their reading of nature along the taxonomy and autecology level which may motivate them to learn the more scientific levels. This is, as I see it, another interesting field of research focussing on the different students attitudes towards fieldwork. Yet another interesting field to look more closely at might be the problems with linking biochemistry to the natural history of *reading nature*. It would be interesting to investigate different ways of introducing the scientific concept of matter and linking it to the reading nature content. Several researchers (e.g. Eskilsson, 2001) suggest that a basic particle model can be introduced to young students. The interesting point is whether the student find the particle model useful when *reading nature*. Holgersson & Löfgren, 2004) found that discussions about different types of phenomenas which include transformation of matter triggered different types of discussions. For instance did the burning of a candle trigger a discussion on a molecular level with upper primary school students whereas the same students were talking about pieses of leaves when they discussed decomposition of leaves. Maybe the biological phenomena does not lend themselves to a discussion an atomic level with young students. Research in this issue is directly relevant to my suggestions about starting with decomposition as a more intuitive process than photosynthesis regarding the scientific level of reading nature mentioned in the implications for future teaching and learning.

15. ETHICAL ASPECTS

Concerns about the investigation to be conducted in an ethical manner are common to all research (Merriam, 1998). It is important to inform the persons thoroughly about the aim of the research and to obtain informed consent. This was sought realised through providing the pupils, their parents and the teachers and teacher students with written and oral information about the project. All participants were told that each of them were free to change their minds about participating in the study at any time. All names in the thesis are fictious and the descriptions of the participants were made with the ambition that they would stay anonymous. With the primary school class a video film was made. The film was published on internet with a title that did not associate to the activity and would be very difficult to find using the search engines on internet. The only sources for the address to the film are in paper III and paper IV and in this thesis. The film was published after a signed agreement from every participant in the film or their parent/s or guardians. The film was presented to the teacher for verification of the relevance of the content. The teacher expressed a support for the content of the film as "It is representing the progression very well and it gives a representative image of the activities and the learning situations.

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Paper I

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RESEARCH REPORT

Student-Teachers' Ability to Read Nature: Reflections on their own learning in ecology

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This paper addresses student-teachers' ability to *read nature* in a woodland habitat before and after a 10-week ecology course. *Reading nature* is our definition of the ability to observe, describe and explain basic ecology in the field. Data consists of field-based pre-course and post-course interviews followed up by metacognitive interviews where students analyse their own learning. A bi-dimensional coding scheme is adopted to examine the range and development of students' ability to *read nature*. Students find it important to know the ecology of a few key species and they recognize the importance of having learned the language of ecology — *ecologish* — helping them to describe and discuss ecology. Students generally recognize the excursions as key learning situations in ecology education but they give different reasons for finding excursions so important. This variation will be elaborated in the paper together with the implications for teaching ecology.

Introduction

Ecology, with its roots in natural history, has evolved into a broad field dealing with scientific studies of the interactions determining the distribution and abundance of organisms. What makes ecology exciting, rather than an endless list of things to be learned about organisms, is that it studies a living, working system. Since human beings have an important impact, directly or indirectly, on this system, the line between ecology and topics such as environmental education and education for sustainable development is hard to draw as ecology is a natural part of these topics. Over the past decades there has been a shift of focus in environmental studies away from ecology and closer to the social sciences (Palmer, 1998).

We welcome this shift but we also want to stress the necessity of ecological understanding when dealing with environmental issues. As Slingsby and Barker (2003, p. 4) put it:

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> the contribution of the biology teacher to education for, in and about the environment is of course to provide a scientific perspective but one that goes beyond providing factual information.

In this study we are interested in future biology teachers' ability to *read nature*. By this we mean their ability to bring the understanding of classroom ecology outside into real natural settings. The ability to go out into an ecosystem and recognize organisms, understand processes taking place and to see the human impact in the particular ecosystem is complex. This involves both the factual ecological content knowledge but also the ability to discern anthropogenic influences on natural processes and to relate these to environmental issues. We see the ability to *read nature* as an important part of the repertoire of a biology teacher — but do our future biology teachers learn this and to what extent do they have this skill when they start their university studies?

In this study we have followed a group of student-teachers before and after a 10-week ecology course. As already mentioned, *reading nature* involves both content knowledge and field experience. Our analysis of the students' developing ability to read nature is based on a two-dimensional coding scheme. The first dimension concerns their compatibility with expert knowledge, and the second dimension their ability to link ecological theory with the authentic ecosystem when they are out in natural settings. The combination of these two dimensions has been our tool for analysing their development towards an ability to read nature. The coded interview data is from the pre-course and post-course interviews with the students. As a second part of the study, the students have reflected on their own learning during the course and on their ways of describing nature before and after the course.

Reading Nature, Ecology and Ecological Literacy

If we start by defining the concept of ecology we soon notice that every text book seems to have its own definition, similar but not identical to the others. We decided to chose the very short definition the students find in their course literature (Reiss & Chapman, 1999): 'Ecology is the study of organisms in relation to the surroundings in which they live'. Furthermore, the authors emphasize the complexity in the field by describing ecology as an enormous jigsaw puzzle where each organism has requirements for life that interlock with those of many other organisms. We see ecology as a scientific field with a tendency to amalgamate with other disciplines and form interdisciplinary fields such as environmental education. If we see ecology as a scientific field it is interesting to see the history of the well-known phrase 'ecological literacy'. This phrase is a re-conceptualization of the phrase *environmental literacy* that Orr (1992) refined to *ecological literacy*. Orr does not identify any differences between the phrases and uses them interchangeably (Cutter-Mackenzie & Smith, 2003). According to Orr (1992) ecological literacy primarily constitutes 'knowing, caring and practical competence'. Orr further implies that ecological literacy encompasses an understanding of 'how people and societies relate to each other and to natural systems, and how they might do so sustainably'. In other words, knowing how the world works and the dynamics of the environmental crisis, and thus knowing how to preserve and maintain the environment. As Cutter-Mackenzie & Smith (2003) write, ecological literacy is ideally about developing a rich knowledge base and multifaceted beliefs and/or philosophies about the environment, which lead to ecological sustainability. Turning to our phrase *reading nature* we see the ability to *read nature* as an important aspect of ecological literacy. Its focus is on ecology and the context is outdoors. The literacy has to do with an ability to recognize organisms and relate them to material cycling and energy flow in the specific habitat that is to be read. It has to do with authenticity where the book to be read is the natural world that we face outside and the tools we have are our experiences from previous learning situations both in and out of doors.

Research on Students' Understanding of Ecology

Existing research on adults, who in this case are student-teachers, is rather limited but research on pupils' learning and understanding of ecology is extensive, and the literature suggests that developing an understanding of ecosystems and their functioning is difficult. Leach and colleagues did a cross-sectional study of 5-year-old to 16-year-old students and their understanding in ecology. They found that the function of the ecosystem is not seen as an interrelated whole by students; that is, photosynthesis, respiration and decay are not related to a view of the cycling of matter in ecosystems (Leach et al., 1995, 1996). Children tend to use simple linear causality when describing relationships in nature where only one population directly affects another (Goldring & Osborne, 1994; Grotzer & Basca, 2003; Helldén, 2003). Also Palmer (1998) has shown that high school students believe that a change in one population will only affect the other population if the two are related in a predatory–prey relationship and it will not affect several different pathways of a food web. The list of research on difficulties in understanding the content of ecology is extensive. But why is the understanding of ecology so limited? Magro et al. (2001) have shown that secondary students often consider ecology education as cut off from real life and not appealing to them since they are not familiar with the species nor the dynamics presented. Students learn the textbook examples of how these organisms interact and relate to non-living factors but they are limited to these examples and have problems when asked to generalize their knowledge. Familiarity with the organisms involved in the teaching seems to be important for generating motivation and interest in ecology education. This echoes our own experiences as biology teachers.

If we turn from pupils to adults, in this case student-teachers, we mentioned earlier that there are only few studies available on adults in ecology education. One of them is Carlsson's (2002) study on ecological understanding. She followed a group of student-teachers and found that when students see photosynthesis, recycling, and transformation of energy as an integrated system, characterized by mutual dependencies, completely new ways of thinking emerged. After the idea was perceived, additional aspects seemed to open up new dimensions, which increased the inclusiveness and generality, and thus the power, of the thinking to explain and understand ecological matters. The idea of transformation seems to be crucial for developing this higher-order thinking and the ability to see the functioning of the ecosystem as a whole in which plants are the basis for survival of other organisms.

Purpose of the Study

The purpose of this research project was to describe how students are able to *read nature* as a result of an ecology course. The ecology course is compulsory for the secondary science student-teachers. It is given in their seventh semester and comprises 3 weeks of taxonomy and 7 weeks of ecology. During the first weeks, when the focus is on taxonomy, students often collect plants and invertebrates around the university. In the following weeks the students have lectures, laboratory work and they go on excursions to different biotopes. In total the course comprises 140 hours of face-to-face teaching where excursions and lectures make up almost 60 hours each. A small number of lecturers (three or four) are involved and they often combine taxonomy and ecology during field work. The course aimed to give the students a broad ecological understanding but what we define as the ability to read nature is not expressed in the course curriculum nor tested in the course examination.

In this paper we also want to illustrate the students own reflections of their developing ability to read nature and their own views of when and how they learned this. This can be addressed by the following research questions:

- How do students *read nature* before and after a course in ecology?
- In which ways do the students see their own developed capability to *read nature*?
- What are the students' views of important learning situations during the ecology course?

An overall image of the research design is illustrated in Figure 1.

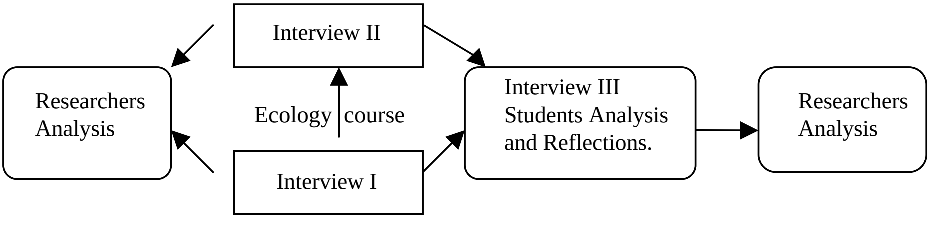

Figure 1. The design of the study. Interviews I and II are analysed by researchers in order to describe students' developing capability to reading nature. The students also analysed interviews I and II but their focus was on describing their own learning. Students' reflections of their own learning was discussed with the researchers in Interview III

Methodology of the First Two Interviews

In this study we analyse three interviews. The first two interviews (interview I and interview II) were conducted outdoors in an ecosystem, before and after the ecology course. The students were asked to describe the ecosystem and explain what they saw. In order to structure our analysis and compare the students' responses in the two interviews we have used a modified coding scheme from Hogan and Fisherkeller (1996). Basically, the responses are coded along the two dimensions; compatibility with expert knowledge and elaborateness of their descriptions. The reason for using a bi-dimensional coding is that we need to take into consideration both the quality of the content knowledge and the ability to actually make use of the surrounding nature when discussing the ecosystem. This will be illustrated as graphs.

In all, 18 respondents from a class of 25 students were involved in the study. The students not involved were either living far from university and not able to stay for interviews after lectures or they were missing at the second interview. The characteristics of the respondents were varied in terms of gender, age, background and domicile but they have in common that they are all in their seventh semester of the science teacher programme for secondary school.

The method used for collecting data was group interviews. We chose to use interviews for a number of reasons. First, it enables us to begin in a very open-ended manner by asking students to describe the ecosystem. This gave us a sense of what objects in nature students could relate to and what experience they have of reading nature. Second, the open-ended questions gave us the opportunity to follow them up by more targeted questions depending on the student answers, thus making each interview unique and possibly revealing important information that would have been difficult to gain by other forms of data collection. Another important reason for choosing outdoor interviews is that we strive for an authentic situation were students relate to things before their very eyes and they should have the opportunity to explore nature during the interview.

Students were divided into seven small groups. Interviews I and II were semi-structured and open ended, with a focus on eliciting the students' ways of describing the natural environment they were in. The opening question was always: 'Please describe this ecosystem and try to explain why it looks the way it does'. The following topics were discussed with all the groups: the *organisms*, the *cycles and processes* and the *human influence* in this particular ecosystem. The interviews were recorded and transcribed verbatim.

Bi-dimensional Coding Scheme

A typical approach to judging the quality of students ideas in science education research is to compare their ideas with canonical scientific conceptions, using rating schemes such as 'sound understanding', 'partial understanding', 'alternative conceptions', or 'no understanding' (Haidar & Abraham, 1991) In order to describe the progression of students' understanding, different taxonomies have been developed.

As an example, the SOLO taxonomy describes level of increasing complexity in a student's understanding of a subject as passing through five stages from a concrete level to more abstract levels (Biggs & Collis 1982). In this study we want to illustrate the development of students' ability to *read nature*. Hence our focus is on two dimensions of understanding. The first dimension has to do with the compatibility between student and expert knowledge, which is equivalent to the first example earlier. When discussing ecology students often mix statements of concrete character, such as mentioning different species or structures, with statements or explanations of systemic character on a higher level of abstraction. This multilevel explanation in ecology makes it difficult to use the most common forms of taxonomies for evaluating students' understanding. Therefore we added a second dimension in our analysis, which has to do with students' ability to apply their ecological understanding to an authentic ecosystem. This linking between theory and practical field application of knowledge is of key importance in our concept of *reading nature* where memorization of field experiences should be a tool helping students to interpret new experiences in the natural world.

Hogan and Fisherkeller (1996) originally made a bi-dimensional scheme to portray students' quality and depth in understanding decomposition in an ecosystem. Their reason for not only looking at the first dimension (i.e. compatibility) was that students given the label 'compatible' could have the ideas very shallowly rooted in their minds. At other times, ideas that looked incoherent were well supported and coherent within the student's own mind. This means that the coding scheme can reveal students expressing a compatible description that is not well elaborated in their minds, and vice versa. We decided to adapt this scheme to illustrate students' ability to read nature. The main idea is to analyse interviews along two dimensions, compatibility and elaborateness.

The compatibility dimension is graded into the following grades:

- C = Compatible. Statements agree with expert propositions. Students either have a large number of correct examples of organisms presented or they describe processes or impacts on nature on a sufficient level in a correct way with very few or any disagreements with expert propositions.
- G = Generally sound. Students make statements or relate to organisms in a compatible way but essential details are missing and a few statements do not agree with expert propositions.
- I = Incompatible. A large number of essential statements disagree with expert propositions and a very limited number of correct organisms or relations are given. Contradictory statements are often found in two parts of the transcript in response to different questions on the same topic.

The second dimension illustrates how well they relate to the physical objects in the ecosystem when describing the ecosystem in an outdoor situation. Criteria for the second dimension are:

- E = Elaborate. Students make many connections between theory and concrete objects in the ecosystem, and discuss these in a complex and holistic way

- S = Sketchy. Students make few connections with the concrete objects in the ecosystem. Not sufficient detail is given to show how they relate theory to concrete objects. Essential details are missing and a holistic view is not given.
- N = Non-linked. Statements are not linked to the concrete objects of the ecosystem. Responses often seem to be given without any connection to the real ecosystem. Rather like school-book content presented out of context.

Our coding scheme is different from that of Hogan and Fisherkeller in the sense that we have three grades for each dimension instead of the original two. The reason for this is to make the judgement on a scale that suited our purpose better. One can argue that only having three grades is limiting but when we did our coding we found it sufficient enough in our judgement of their ability to read nature.

In the first dimension we need to correlate statements to expert ideas of the topics. The expert criteria have been negotiated with the lecturers on the course and correlate to the content knowledge presented to the students in the course. High-achieving students are expected to reach this level after the course. In the following, we have made a short description of what we consider to be expert propositions or expert levels in the three topics:

(a) *Organisms and non-living factors*. The most common organisms in a familiar habitat can be recognized and categorized into producers, consumers and decomposers. A forest can be described in layers from canopy layer down to ground layer with a large number of organisms, not only plants, in each layer. The organisms occurring reflect the non-biological factors such as light, humidity, soil structure and richness in nutrients.

(b) *Cycles and processes*. All nutrients, including carbon dioxide, oxygen, minerals and water are cycled and appear in the non-living environment or as part of the organisms' bodies in the living environment. These nutrient cycles are driven by the energy from the sun through the system with an exchange of materials resulting from biological, geological and meteorological processes. Succession is a natural change in the structure and the species composition of a community. Life strategies and linear and cyclic processes in nature can be exemplified and distinguished from each other.

(c) *Human influence*. In the ecosystem there are direct and indirect influences from human activity. The direct influences, on a small scale, are physical constructions such as roads, paths and the results of forestry actions such as logging or planting. On a larger scale the whole area has a long history of agricultural land use shaping the whole area. The indirect influences are less obvious in this area but include the air pollution affecting the soil and vegetation.

Our definition of *reading nature* includes the content knowledge already described together with the students' ability to correlate this content knowledge to the biological and non-biological features in the ecosystem; that is, to apply the theory to the actual experiences in the natural world outside. This means that, according to our definition of *reading nature*, students should reach the compatible and elaborate level in all the three topics mentioned.

Data Analysis

During the analysis of interview I and interview II we focused on students' discussions relating to the three topics mentioned earlier. Each interview lasted between 15 and 30 minutes. The data were rich, but to give an insight into these interviews we have chosen to present a short excerpt from the first minutes of interview I and interview II with the students Carol and Edith. This group has been selected since it is not among the stronger nor the weaker groups in the compatibility and elaboration dimensions, but rather somewhere in between. Our judgement of their whole interview I and interview II is illustrated in Table 1, where they are group number 1.

In this excerpt the topic analysed is Organisms and Non-biological factors.

Interview I

Interviewer: Please describe this ecosystem and try to explain why it looks the way it does.
Carol: There are some old oak trees.
Edith: Yes some small and large trees. I think that one is an elm tree.
Carol: Yes and that is probably an elder bush.
Edith: Yes, and that is grass, tall grass. Yes and there are some rocks and that plant looks like a fern.--//--

Table 1. Bi-dimensional summary codes for student description of ecosystems: Interviews I and II

	Code					
	Organisms		Cycles		Human impact	
	Interview I	Interview II	Interview I	Interview II	Interview I	Interview II
Group 1	GS	CE	GN	GS	GS	GE
Group 2	GN	CS	GN	GS	GS	GS
Group 3	GS	CE	GS	CS	GS	GS
Group 4	GS	CE	IN	GS	GS	CE
Group 5	GS	CE	GN	GS	GN	GS
Group 6	CS	CE	GN	GS	GS	CE
Group 7	CS	CE	GS	CS	GS	CE

Note: Each of the codes expressed is bi-dimensional; that is, each code delineates a combined judgement of the level of compatibility and the level of elaboration of students ideas. First dimension: C, compatible — statements concur with expert propositions; G, generally sound with a few (minority) statements not agreeing with expert propositions; I, incompatible — statements disagree with propositions. Second dimension: E, elaborate — statements relate to the ecosystem in a complex and holistic way and have sufficient detail to show the thinking behind them; S, sketchy — only few details and logic given, essential details are missing and no holistic view is given; N, non-linked — tatements are not linked to the ecosystem, rather like school-book content presented out of context without correlation to the surrounding nature.

Edith:	Why it looks the way it does..mmm well it probably has to do with t it being a glade and the plants living here need a lot of light, maybe.
Interviewer:	mm.
Edith:	I mean they don't grow deep in a forest like spruce does. It is more of broad leaved trees so it is less dark. Here it is glade plants.
Carol:	Maybe the soil is important.
Edith:	Humidity.
Carol:	and light yes that's it.
Interviewer:	Why? Can you explain what you mean?
Carol:	mmmm. It is difficult …

These interview excerpts have been interpreted as generally sound (G) along the compatibility dimension, and sketchy (S) along the dimension on elaborateness (GS).This is since the students only mention a small proportion of the occurring organisms, and only vascular plants, but those mentioned are correct and dominant in the ecosystem. The non-living factors are presented in an incoherent way and there is a short list of essential factors for life in any ecosystem. It is not elaborated nor strongly linked to this ecosystem and it lacks a holistic view.

Interview II, 10 weeks later

Interviewer:	Please describe this ecosystem and try to explain why it looks the way it does.
Carol:	Well, yes we think that the tree layer consists of some oak trees and ash trees.
Edith:	Yes and elm trees.
Carol:	Yes and it is not so dense in the tree layer, there are lots of open areas, I mean it is not only a tree layer as it is in a beech forest, but here is also a well developed shrub layer and herb and ground layer.
Edith:	Yes, the brush layer is dominating isn't it?
Carol:	Yes with small oak bushes becoming trees and maybe that is elder bush?
Interviewer:	mmm.
Carol:	Oh, good I said that the last time as well but I didn't know if it was right. [laugh]
Edith:	and grass of many species. Some flowering plants and a fern, maybe? Yes and there are a lot of different mosses on the ground and also lichens on the trees.
Carol:	Yes lots of lichens and we didn't notice that the first time. --//--
Edith:	The soil must be rather rich here. I mean since there are oaks and ashes. They don't like to grow on podsol, right?
Carol:	mm yes, it must be more rich in nutrients here.
Interviewer:	Nutrients?
Carol:	Yes minerals and salts. --//--
Edith:	But worms are common here. We can see the faeces. And bacteria I'm sure. It must be a lot of bacteria and other decomposers since it is not such a thick layer of leaves or fauna here. One can see that it decomposes rather quickly. Yes it is a rapid turn-over rate here compared again with a beech forest where you can walk around and kick the leaves with thick layers underneath.
Interviewer:	mm why is it so?

Carol: Well it is because in a beech forest you don't have the same decomposers as you have here. It is more fungi there because the pH-level is lower.. Here there are s more of springtails and pillbugs.
[starts lifting pieces of wood]
Carol: Yes look the springtails are jumping away.

The second interview has been interpreted as compatible and elaborate (CE).

In the first dimension the students mention a number of organisms, both animals and plants including mosses and lichens. They also link the organisms to the ecosystem and make comparisons with other ecosystems. They can elaborate on the differences between the decomposers in this forest to decomposers in other types of forests. Later on in this second interview, but not included in this excerpt, they also mention the importance of minerals from the bedrock, such as calcium carbonate, for the flora and fauna in this forest. We find that the students have moved from a short and sketchy description in the first interview to an elaborate description much more related to what they actually see in the forest.

In our analysis of the whole group (Figure 2) we have seen that in the first topic (organisms and non-biological factors) most groups improve their ability to recognize the organisms in the forest. All students have a strong focus on the plants the first time, as we saw in the example of Edith and Carol, but the second time they mention many more organisms and they have a more elaborate way of describing them. The non-biological factors of light and nutrients are mentioned by all groups the first time

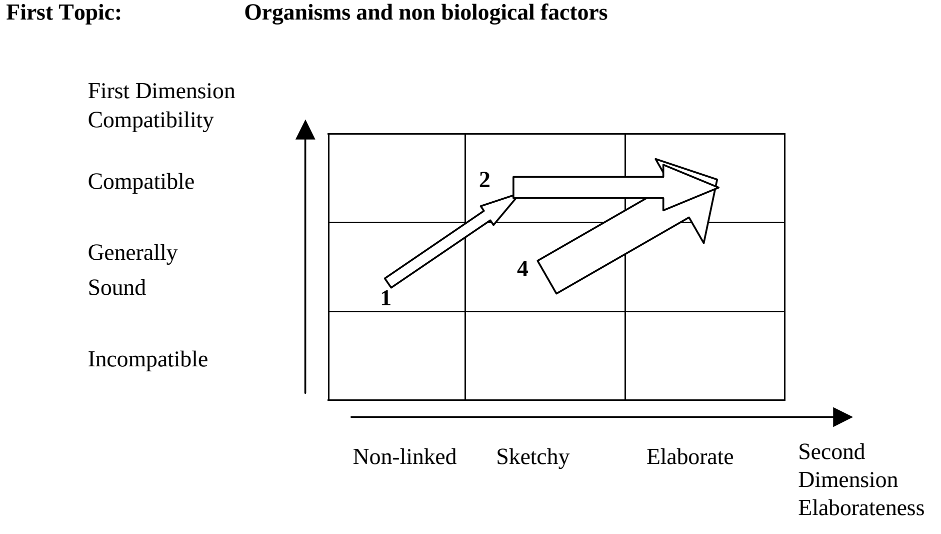

Figure 2. Diagram illustrating the development along the two dimensions between the pre-course and post-course interviews: students developing understanding of organisms and biological factors between interview I and interview II. The base of the arrow indicates the position at the pre-course interview. The point of the arrow indicates the position at the post-course interview. The size of the arrow together with the number indicates how many groups ($n = 7$) represent each specific development. A star in the diagram indicates no development between the interviews

but often in a sketchy way, not linked to the ecosystem, whereas the second time most groups elaborate more on this. The autecology and demands of some of the tree species in relation to light and soil quality seem to be an important key to their more elaborate reasoning the second time.

The second topic (cycles and processes) is more difficult to analyse. All students mention photosynthesis in the first interview and most (four groups) of the students consider it as something very easy and basic, not worth going into details about. Despite this, one group misses the importance of carbon dioxide for plant growth. Cycles and processes seem to be difficult to link to the surrounding natural world and in the first interview they often give a sketchy description (Figure 3). In the second interview they often mention succession and see a strong relation to the ecosystem. Decomposition is mentioned by most groups (six groups) in both of their interviews, but some (three groups) illustrate it the second time by linking it to the decomposers they see or with relation to the amount of dead organic matter they can see. This topic demands students' ability to describe theoretical models, not directly visible in nature, and link them to this forest. The application of theoretical models to live examples seems difficult to do.

The third topic (human influence) seems to be very easy to see at the level of direct impact. When answering the question 'Can you see any traces of human influence in this ecosystem?', the direct impact such as road constructions and logging in the forest is detected and described by all groups, also in the first interview (Figure 4).

Second Topic: Cycles and processes

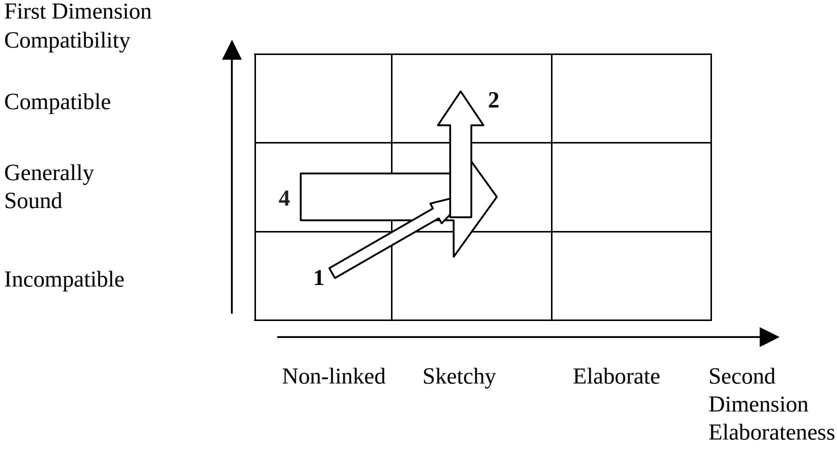

Figure 3. Diagram illustrating the development along the two dimensions between the pre-course and post-course interviews: students developing understanding of cycles and processes between interview I and interview II. The base of the arrow indicates the position at the pre-course interview. The point of the arrow indicates the position at the post-course interview. The size of the arrow together with the number indicates how many groups (n = 7) represent each specific development. A star in the diagram indicates no development between the interviews

Third Topic: Human influence

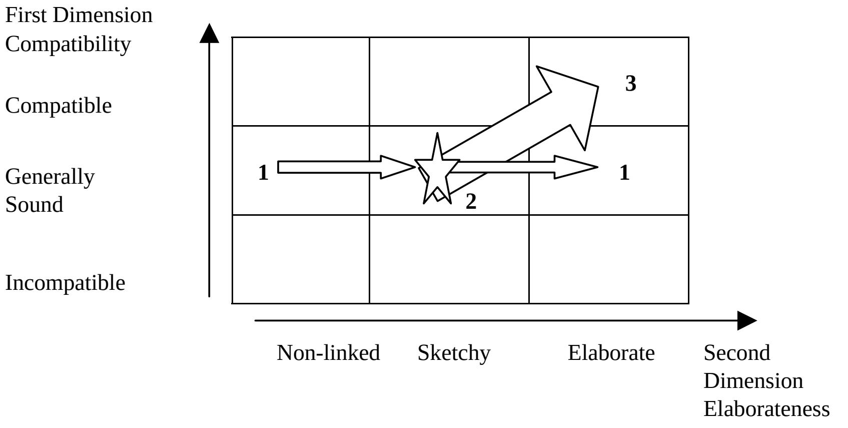

Figure 4. Diagram illustrating the development along the two dimensions between the pre-course and post-course interviews: students developing understanding of human influence between interview I and interview II. The base of the arrow indicates the position at the pre-course interview. The point of the arrow indicates the position at the post-course interview. The size of the arrow together with the number indicates how many groups (*n* = 7) represent each specific development. A star in the diagram indicates no development between the interviews

But to reach the compatible level students are expected to recognize more indirect influences, such as acidification, introduction of species, draining, and so on, which seems to be more difficult. In the second interview most groups mention at least one of these indirect influences of humans. They often link the lichens they see to the air quality, apparently something they studied during the course. Most groups also discuss the structure of the forest in relation to forestry actions like clearing and replanting that has taken place in the forest. In this topic students give a lot of examples from the ecosystem but they do not elaborate very well on the reasons behind what they see. This is the opposite of the second topic where they often give correct explanations to the cycles but rarely link it to the ecosystem.

Methodology and Analysis of the Third Interview

The third interview was conducted 2 weeks after the course had finished and it had a metacognitive focus. Each student received an audio-tape with his/her interviews I and II. In preparation for the third interview each student was asked to listen to the tape and make notes reflecting his/her own learning. This metacognitive format was planned in order to gather relevant information on students' own ideas about their developing understanding. They were asked to reflect on the development of their own ability to read nature. They were also specifically asked to comment on their own view of their learning to read nature and whether some instances were more important than others for the development of this capability. The interviews lasted for approximately 1 hour. They were conducted indoors with the same groups as in interview I and interview II but, initially, each student individually reflected on his/her learning followed by a semi-structured group discussion. It is worth noting that our expression 'reading nature' was not mentioned and explained until the students were asked to reflect their own learning. During interviews I and II we never used the expression.

Using a metacognitive format can bring up interesting personal views on learning that in a normal teaching situation are not visible and in course evaluations rarely come to surface (Bransford et al. 2000). The familiar difficulties embedded in the analysis of other people's understanding, with this methodology, is reversed and in this study we put the student first, giving us a first-hand reflection of their view of their own learning. Experience indicates that we can learn more about a person's learning by letting them reflect on their own learning (Helldén, 2004). Most students found it very exciting to listen to their interviews and more than one-half of them expressed surprise at how little they seemed to know in the first interview. In the second interview seven students still expressed discontent with their ability to apply their theoretical knowledge to a real-life situation (i.e. *reading nature*). An important reason for the frustration of these students was that they all considered reading nature to be an important skill for a biology teacher.

When analysing the students' reflective comments, three things stood out as important to every student:

- The language of ecology as entering into a new discourse.
- The change of perspective as seeing the world with new eyes.
- The excursions as important events for learning ecology.

The Language of Ecology

The languages of science are rich in contextual semiotic resources but in this paper we chose to restrict it to the spoken language of ecology. This means it is limited to the linguistic registers and genres of the field: their vocabularies, their semantic networks and their styles of discourse.

> I used to know something about nature in Swedish but now I know a lot more and I speak Ecologish, a better and more precise language.

As exemplified by Patric in this statement, there is an awareness of a developed language named Ecologish, facilitating student discussions about nature. Learning science means learning to talk science (Lemke, 1990). Each scientific discipline has its own semantic, and learning to express relationships between its concepts is of key importance in mastering a discipline. The literature on the semantics of science is extensive but the analyses are usually based on the researchers view and not, as in this case, the students' own views.

One way of describing the relationship between 'ecologish' and a natural language such as English is in terms of the linguistic notion of *register*. Halliday

(1978, p. 65) specifies this notion as ‘a set of meanings that is appropriate to a particular function of a language, together with the words and structures which express these meanings’. One function to which a language can be put is the expression of ecological ideas and meanings, and that is when an ecological register will develop. The words and structures in ‘ecologish’ are important for putting labels on different organisms in order to help to discern biodiversity and recognize the communities and relationships between some of the common species or functional groups in an ecosystem. But that is not all, the language ‘ecologish’ also includes the meanings and ideas behind the concepts. Since *reading nature* has to do with understanding ecology on a systems level, the language ‘ecologish’ involves not only appropriate names for the structures in the ecosystem but also for their underlying functions, behaviours and mechanisms in the ecosystem. The functions refer to the role the structural parts play in the larger system in which they are embedded. Behaviour refers to the dynamic processes and changes in structures, while mechanisms refers to the causes of the behaviour (Buckley 2000). Development of this type of coding schemes for systems understanding in science is detailed elsewhere (Boulter & Buckley, 2000; Buckley, 2000; Hmelo-Silver & Green Pfeffer, 2004) For a deeper analysis of the semiotics of ‘ecologish’ in relation to systems, understanding this type of coding can be a valuable tool in our future research.

To illustrate students’ reflections on their own learning we have selected Edith’s and Carol’s (group 1) reflections on the first parts of their interview I and interview II. Other excerpts from these interviews are presented earlier in this paper. This gives an opportunity for the reader to see how interviews I, II and III are interrelated and to follow the argumentation of the students.

Edith: We explain things on a completely different level. I sat at home thinking about how I could express this but … yes, you have a completely different perspective on nature. You don’t focus on details but rather try to explain the larger picture and then afterwards you can explain it on a smaller scale.

Carol: I felt much more secure the second time. We could answer much more precisely and not so fuzzily. Yes, the same questions in the interview were understood in a different way the second time

Edith: Yes, the first time it was a little about bushes and trees and the second time we mentioned the different layers and we could go straight into the answers and answer them in a more secure and better way. We looked at the nature in a different way and had a different language.

Carol: Yes.

Edith: We knew so much more about the species and their demands For instance the lichens and their relations to air quality. We didn’t even see them the first time. And the oaks and why they are there. Yes I saw nature with different eyes. And species richness. The first time I said that there probably are some 20 organisms in the area we were looking at. Now I know that there are so many more and I can recognise many of them. Know their names and that is great.

Carol and Edith recognize that they have learned a new language. In the interviews all the 18 students spontaneously mention a richer language as one of the most obvious differences between interview I and interview II. Language as an important part of their improved ability to read nature seems obvious. It also seems to give them 'a completely different perspective on nature'. They see structures and they do not look at the details but rather at the larger picture. Species and their demands are also mentioned as important. To illustrate how the students elaborate on the importance of a new language we present a short excerpt from two other students, Janet and Jonathan, who express in a well-defined way what most other students say.

Jonathan:	We talk a lot more the second time and use a different language. We use expressions we have learned and it makes it much easier to express yourself with these words.
Janet:	Yes, you put the finger on what it is. You become more precise. The second time you also see much more and we mention mosses and lichens, tree layers, podsol and abiotic and biotic factors etc.
Janet:	We have learned a lot of new names.
Jonathan:	Not only names. It is the adequate expressions for phenomenon. It makes it easier to classify things into categories. And it makes it much easier to express what you want.
Janet:	Yes, we describe things more accurately and straight forwardly. No fuzzing around. Yes, OK, we have widened the reference frames, definitely. The concepts are deeper.

Janet and Jonathan mention that they use a new language to be more precise, and one example of this is that in the second interview they describe the forest in its layers from the tree layer down to the ground layer. This has been mentioned by Carol and Edith and three other groups as well, and it is obviously a meaningful way of describing the forest that has been taught during the course. Another example is the concept of nutrients, which is considered problematic in many other studies (Driver et al., 1985; Helldén, 2003; Leach et al., 1996) and, for most groups, is used in a much more elaborate way the second time where it is a useful link between flora and soil. Some ecological concepts are used by many of the students only in their post-course interviews. These concepts seem to be important for their descriptions of the ecosystem and could be considered to be discursive tools helping the students to explain features and phenomena in the ecosystem. In this study the most common of these concepts are: succession, competition, habitat, biodiversity and niche. Ecology is a discipline rich in concepts, but when analysing what the students actually use of this diverse terminology they have not added many more concepts than those already mentioned. As Janet says, the concepts have become deeper. By this she means that the same concept has a deeper meaning, not so vague, the second time. Nutrients is an example of this, mentioned earlier.

Species Knowledge a Part of Ecologish

The most common reason students give for their developed capacity to describe the ecosystem in the second interview is the species knowledge. Every student mentions this as very important. Jonathan and Janet see this as a new language:

Jonathan: Species knowledge is like a language. You need to have the right names to be able to communicate. It's like a car salesman. Without accurate names on the models he couldn't talk about them and sell them.

Janet: Yes, it helps to know the species when you want to describe an area instead of only having ecological words. Maybe our lecturers can describe nature without having the species names. They have come further and can describe the criteria for life in an ecosystem without the species names I think. Maybe not, eeee. You need the names after all.

The importance of species knowledge in describing nature had already been stated by the Swedish eighteenth-century scientist Carl Linnéus when he wrote '*Nomina nescis perit et cognita rerum*' ['If we don't know the names the knowledge of the things themselves is worthless'] in 1737. He was pointing to something of great importance in field ecology — the necessity of familiarity with the species and their names. The names are important as a part of the language of ecology. You have to be able to communicate with this language when reading nature. A certain level of species knowledge seems to help the students to pick out the known organisms from the undifferentiated wall of chlorophyll, which is how the forest appears for the uninitiated. Students say '*we now see nature with new eyes*' (Edith). This is a well-known general phenomena stated by Bransford et al. (2000) that expertise in a domain is characterized by sensitivity to patterns of meaningful information that might not be available to others dealing with the same problems within the same domains. Reading nature is about discerning the organisms and being able to communicate them, as Jonathan and Janet stated in the previous excerpt. This change of perspective when you see nature with new eyes has been illustrated in Magntorn and Helldén (2003) and will not be elaborated in this paper. In the case of species knowledge as a language, interviews I and II indicate a significant improvement that is clearly supported by the students' reflections.

Different Views on Excursions as a Learning Opportunity

> Field work often leaves a lasting impression and promotes a deeper understanding of the experimental, analytical and interpretative approaches that underpin the whole of science and the way in which the world around us really works. (Barker et al., 2002, p. 4)

This quote is taken from the introduction in a report on the importance of field work in schools. Is this statement relevant for the students in this study when they describe important components of the course that help them to learn to *read nature*? We find that all students recognize excursions as being very important for their learning. When we analyse their reasons given for this claim we find an interesting variation based on their views of their own learning. We illustrate this variation of reasons by describing the views of three students, Thomas, Cathy and Edith.

Thomas

Thomas is an average student who in the past has not been very interested in nature and has very little experience of nature studies except for the biology teaching in school, which, according to him, was very rarely taught outdoors. During the course he has changed his attitude towards nature studies and has become very interested. The lecturers on the course confirm this change and he is characterized as an 'explorer' who enjoys observing things in nature and who can draw conclusions from what he sees.

Attitude: Fascination.

> mmm and another thing that was fascinating was that it is such a big difference between running water and a lake. I mean the adaptations that they have to cling on to things and so in the rapid water I mean how they solve these kind of problems. This was new and then you start looking for these differences in adaptation when you look at flying insects as well. Fascinating I think.

View on excursions: Exploring nature.

> I think the most important for me has been to really be out in nature and explore it with teachers who know it very well. The lectures were more a complement to reading nature. I believe that I have thought a lot during the excursions on things we have mentioned during the lectures and labs.

View of his own Learning: Sudden connection.

> I mean you have connected with this specific knowledge even if we have studied too many things but some of them could be related between theory and excursions. Then I learned it. It was simply not only that this is a scrophulariaceae and that is a bumble bee but rather that I look carefully at where it lives. Then when you are out collecting them, then it struck me that — wow, yes of course that's how it is. Now I understand. As when you were collecting insects for instance you all of a sudden saw that in these plants you have that sort of flies. You could connect these things in the field.
>
> I see things in nature Yes, often the learning is when it is least expected. The knowledge is laying latent in the back of my head and when you trigger it by seeing something or remembering something there is a sudden connection.

The bi-dimensional coding for Thomas and his group, including two more male students, shows a move from sketchy or non-linked statements in the pre-course interview to a more elaborate way of describing nature after the course (Figure 5). The compatibility dimension does not indicate larger improvements.

Organism		Cycles		Human influences	
Int 1	2	1	2	1	2
GS	CS	GN	GS	GS	GS

Figure 5. Bidimensional coding for Thomas' group (number 2). G, generally sound; S, sketchy; E, elaborate

Cathy

Cathy is very ambitious and produces good results in examinations. She says that despite the fact that she was outdoors a lot when she was younger she does not know very much about ecology ‘I have never been really interested in nature, I guess’. The lecturers on the course describe her as ambitious and well organized.

Attitude: Excursions are confusing but fun.

> I only say things that I am certain about. This is very typical when you ask things that we have discussed on the lectures. Then I comment on it but not when we have seen it on excursions only: I think they are confusing and too much to take in at the same time.

View on excursions: Linking theory to practice.

> I only see what the teachers tell me to look at and I don’t learn anything on my own in nature. I like it when the teacher tells you exactly what to do and look at.. I only learn what I’m told to and I have difficulties in generalising and interpreting. I guess I lose interest when it is messy. So it is mainly at the lectures I learn or it falls in place.

View of her own learning: Recognizing.

> Yes, I feel much more confident to take the pupils out in nature now, but it has been difficult for me. Probably the link between excursions and ecological examples on lectures and the ecological discussions have widened my knowledge. I don’t think I ask myself these sorts of questions about why things look the way they do but on the other hand I can recognise things that we have looked at before. I can’t make any new conclusions no I’m limited to what I’ve learned. If I had walked in the forest on my own I don’t think I would have seen very much. I only see what I can recognise.

In the bi-dimensional coding for Cathy and her group, including another female student, there is a move from general to compatible in the first two topics, and the third topic is rated general in both interviews (Figure 6). Along the other dimension they only relate the statements to the nature in the first of the topics.

Edith

Edith has been described before in excerpts from her interviews I and II. She is an average student who enjoys discussing with other students and lecturers. She represents the ideas of the majority concerning their learning during the course. She

Organism	Cycles	Human influences
Int 1 2	1 2	1 2
GS CE	GS CS	GS GS

Figure 6. Bidimensional coding for Cathys group (number 3). G, generally sound; C, compatible; N, non-linked; S, sketchy; E, elaborate

stresses the importance of the excursions as an opportunity to discuss ecology and to link theory and practice, which is what most other students (nine students) say. Her background knowledge in ecology is not very deep but she enjoys being out in nature.

Attitude: Necessary to be outdoors.

> If you are out-doors a lot then you get so much for free. I mean then it is not on paper and you can show things directly for example how the soil differs at two different places and then you look at the environment surrounding it …well yes everything is connected which it is necessary to be outside to see. And then you create your cycles according to what you see.

View on Excursions: An opportunity to discuss ecology.

> I think it is very good to discuss what you can see and understand in small groups out-doors. Yes, like when the teacher was digging in the soil and we discussed what we saw with him as well as all the times we have collected organisms and then discussed what they were and how they lived on the excursions. This has been very important to me. These are parts of ecology that you have to do outdoors.

View of her own Learning: Making connections.

> Yes I think the excursions were the most important part of the course for me. The most positive was that you could always discuss things with the lecturers. That's when I made the connections between organisms and the nature. And afterwards when we had more of the theory and lectures you could reflect back since most of the excursions were in the beginning of the course.
>
> In one of the lectures we first had some theory on succession and then we went out and did a short excursion studying it which was really good. And the mix between taxonomy and ecology on the early excursions was really good. I mean instead of separating the two when they are so closely linked together.

Together with Carol's group. Edith's group show a strong development on both dimensions in the first topic (Figure 7); earlier see interview excerpts.

Students Reflecting on Their Own Learning

We can see clearly the progression in learning but not how they learned at a micro level. Our ambition has never been to illustrate students' learning progression by

Organism Int 1 2 GS CE	Cycles 1 2 GS CS	Human influence 1 2 GS GE

Figure 7. Bidimensional coding for Edith's group (number 1). G, generally sound; C, compatible; S, sketchy; E= elaborate

following the teaching in order to isolate important learning events. One of the functions of the metacognitive interviews has been to collect information from all students and try to isolate events considered important to many of them. The course is a combination of taxonomy and ecology where the first 3 weeks focus on structuring the living world where vascular plants are associated with families and invertebrates with orders or equivalent groups. The most common teaching design during the first weeks is to collect organisms in the field, often close to university, and bring them back to university for classification. During this part the emphasis is on taxonomy. The following weeks are basically lectures and excursions where students visit seven different ecosystems, and their main assignment is to study the organisms in the ecosystem and their adaptations to the various life conditions in the ecosystems. Some excursions (to marine and aquatic ecosystems) involved quantitative field work on the distribution of organisms and their adaptations. Individual field reports after every excursion were written by the students. The lecturers often relate the content of the basic ecology presented in the lectures to examples of phenomena studied in the field. They have expressed their views on the importance of excursions and of learning taxonomy. One factor considered to be a very positive side of the excursions was that the students think they have more time (i.e. less stress). Since many students with varying levels of ambition all express this, we think it is a factor worth considering when planning teaching events. Some students (six students) explicitly mention the importance of starting with taxonomy before ecology. As Carol says 'it made a platform to stand on when you started to look at nature with ecological eyes'. When asked how they learned, many students, in line with Thomas' quotations earlier, argue for the importance of having first-hand experience of nature together with well-informed teachers with whom they can discuss things. The students often have problems putting a finger on how they learn but many find the field discussions helpful where students had to work on an ecological task and then having time to discuss this with the lecturer in the field. These kinds of events were mentioned by many students as important. Identifying species was referred to as very important by most students. This has shown the greatest development. Many students say they knew basic ecology but that taxonomy was something they did not know before and they were positively surprised of how useful it was. Only two students thought they had too much of this. Some students think the taxonomy is of little use if they still lack the understanding of the functions of the species. Autecology is what these students say has helped them most.

Since the course did not have a strong pedagogical emphasis we did not, in the interviews, focus on their views of possible implications for their future teaching.

There is therefore not much evidence for their thinking about this but both Cathy and Edith did spontaneously come up with comments. Edith said:

> I think I will work with my kids outdoors and teach them how to see things in nature and to sit in small groups and discuss this like we did with a lot of follow up questions in the field. Cause when you're outdoors you get so much for free as I said before.

Cathy, on the other hand, did not discuss how she would teach but she said:

> Yes, I feel much more confident to take the pupils out in nature now, I know so many organisms now but it has been difficult for me. Before the course I wouldn't have liked to go out, I think.

If we look at these comments they can be seen as reflecting their metacognitive responses to their own learning. Cathy found it difficult to learn from the excursions if the content was not explicitly connected to theory from lectures. She also tended to see them as messy. In her view of her future teaching she reveals that, without confidence in species knowledge, she would probably not take students out on excursions. Edith, on the other hand, is more focused on the activity in the field where she is influenced by the field work methodology she has met during the course. She does not mention any lack of confidence regarding her level of content knowledge in ecology. We have reasons to believe that the future pupils' of Cathy and of Edith will experience different kinds of field work and excursions. At least if they intend to teach in accordance with their own view of their outdoor learning. Cathy is likely to stress the linking of theories from the lessons to nature and to structure the activities to avoid messiness and confusion. Edith, on the other hand, might want to work with open questions and group discussions about theories and events in the field. Hopefully their metacognitive discussions with others have inspired them to vary their instructions and teaching design enough to inspire future Ediths, Cathys and Thomasses to appreciate outdoor nature studies.

Discussion

If we look at the ecological content knowledge asked for in the course it focuses on three topics: organisms, cycles and processes, and human influence in the ecosystem. Our aim is to see to what extent students develop their ability to elaborate on each of these topics, but also the ability to link them together in order to give a systemic view on nature.

> System thinking competence is the ability and willingness to link different levels of biological organisation from the perspective that natural wholes, such as ecosystems or organisms, are complex and composite, consisting of many parts in active relation and interaction of one kind or another and that the parts themselves may be lesser wholes. (Mayr, 1997, p. 68)

This is obviously a complex ability. Are we asking for too much when we expect future biology teachers to be able to read nature? Is this capability relevant for a biology teacher? In our analysis we see that initially many students have great difficulties in linking schoolbook ecology to the real forest. They have probably been in this type of forest many times before but never been asked to describe it in detail or to explain why it looks the way it does. Most students in the first interview give sketchy descriptive answers to the question *what* rather than trying to give answers to the question that seeks for answers to *why*. After the course the descriptions of nature are more elaborate. Students mention more species and new groups of organisms. Most important is that they know something about the ecology of some key species (i.e. their autecology). This autecology of, for instance, the beech tree is helping students to draw conclusions about soil conditions, decomposition rate and light conditions in the forest. They combine the *what* and the *why* questions. Another example of development is the ability to describe the flora in a structured way, dividing it into separate layers, like tree layer, shrub layer, and so on. Words like nutrients and decomposition are, by most groups, used in a much more elaborate way the second time. The topic that seems most difficult to relate to the ecosystem is the cycles and processes topic. Concepts like succession and decomposition are frequently used in their second interview. These concepts seem relevant and easy to link to the ecosystem but, for example, photosynthesis or cycles of elements in relation to the ecosystem are not spontaneously mentioned by more than two groups. This often have to do with perception where the gas phase of, for instance, carbon is not visible and therefore on a high level of abstraction. This echoes research revealing that these theoretical models are difficult to apply in real situations (Andersson, 1991).

If we look at the results there is generally a strong development in the ability to *read nature* between the two interviews but there is no group fully meeting our requirements for reading nature; that is, reaching an elaborate and compatible level on all three topics. It obviously is a difficult capability we are hoping to achieve.

On the question of the relevance of the capability to *read nature*, a large number of students express frustration when they listen to their second interview. This frustration originates from the combination of realizing the importance of this capability together with the feeling that they did not come up to their own expectations of their ability to read nature in the second interview. The importance of this capability is supported by the Swedish curriculum for secondary biology, which stresses the knowledge of our common ecosystems and their dominating species.

The growth of ecology as a discipline has led to a proliferation of novel terms, definitions and descriptions. Although this is a problem facing any inexperienced student of sciences, it is difficult to think of any other discipline that involves familiarization with such an array of terminology (Tilling, 1993). It is therefore important to try to extract some important concepts for the students. From this study we can extract concepts like species richness, succession, nutrients, soil quality, competition and decomposition, which are mentioned by most students in both of the interviews but in the second they are more elaborated and connected to theories of ecology. From being a word seemingly without much meaning to the students in the first interview it has become more of a discursive tool helping the students to structure their analysis of the ecosystem. The most important of these discursive tools is the organisms and their autecology. Bransford et al. (2000) states that one dimension of acquiring greater competence appears to be the increased ability to segment the perceptual field; that is, learning how to see. Research on expertise suggests the importance of providing students with learning experiences that specifically enhance their abilities to recognize meaningful patterns of information (Bransford et al. 2000: 36). The change of perception exemplified by Edith as 'see the nature with new eyes' is mentioned by all the students as an important part of their learning. Behind this idea of new eyes is the ability to discern the different organisms in the ecosystem and to see structures of nature, where one example is to structure the forest into different layers.

Students also reflect on their different language where they express themselves much more precisely and with more certainty in the second interview. This is described by Lemke:

> Talking science in the fullest sense, always combines a thematic pattern of semantic relationships with a structural pattern for organizing how we will express i.e. construct them. There is a scientific way of describing a flower in botany that is different from how a flower is described in any other context. (Lemke, 1990, p. 27)

There is a special discourse for every professional discipline. Ecology is of course one of them. By using the methodology where students reflect on their own interviews we have made it possible for the students to see how their own language has developed, and students express fascination when they realize the differences between interview I and interview II. One of the students even gives this new language a name — ecologish — which reflects the fact that he sees it as more than only an addition of new words to his Swedish.

As teacher educators we see the excursions as an important part of the ecology course for various reasons. Biological field work provides one of the few places in a science curriculum where students quite literally observe the real world. But the excursions are considered the Achilles heel of ecology in schools. Teachers report that they are afraid of taking students out into nature because they do not feel secure enough on their own knowledge. To be confident in taking the students out into the natural world you need field experience yourself. The majority of the secondary teachers in England considered excursions as the most important part of ecology (Hale, 1993). In this study we have shown that the students appreciate the excursions and the combination of studying botany and zoology together with ecology in the same course. Many teachers find it difficult to do the field work (Barker et al., 2002), and anyone who has been a biology teacher knows about all the factors that can turn a good excursion plan into a catastrophic event. Other notable barriers affecting the provision of outdoor learning in schools are fear and concern about health and safety, shortage of time, resources and support together with curriculum requirements limiting opportunities for outdoor learning (Rickinson et al., 2004). Depending on personality and learning strategies we can see that different components in an excursion are appreciated by different students. We can divide these components into the nature exploring event, the structured nature guiding and the field discussions. This last component of the excursions is dominating what most students list as important learning situations during the course. We see the developed language of ecology linked to this field discussions, and this is an argument for excursions in ecology education supported by the following quotation:

> If learning science is as much about learning the language of science as it is about learning its substantive content, then students must have an opportunity to practice its use through structured activities that require them to talk science, use scientific words and to share and construct their own meanings of these words. (Wellington and Osborne, 2001, p. 84)

Implications

In the introduction we mention Magrot et al.'s (2001) findings that secondary students often consider ecology as cut off from real life and not appealing to them partly because they do not recognize the organisms in the ecological examples. We have found that student-teachers before the ecology course have great difficulties in using nature when they are asked to describe and explain the ecology of a habitat such as a forest. After the ecology course students are, not surprisingly, much better at doing this. One important reason for the development is, according the students, their knowledge of some of the species occurring in the habitat and their ecology. Here we see some important implications for education. First, we see the importance of combining ecology with taxonomy in the course. Students express an appreciation of having only few teachers involved and that those teachers combine the ecology with taxonomy in their teaching, discussing the autecology of important organisms. Second, the excursions are considered very important for learning to read nature and for learning the language of ecology. The most appreciated type of excursion is when students are given the opportunity to discuss ecology in the field and relate it to theories from the lectures. It is also found that different students appreciate different types of excursions. Therefore to give students a variation of learning situations in the excursions or between different excursions is very important.

During the course seven different ecosystems have been studied. We think it may be more effective to focus on only a few ecosystems but at a greater depth. Since some students think they know too little autecology, our idea is that deeper knowledge of a few ecosystems can give students the capability to read nature in these chosen habitats, which are the habitats most likely chosen to work with in their future careers as teachers. Finally, we consider that the methodology where students become aware of their own learning is an effective way of helping them to understand their own learning process. This can be of great help when they as professional teachers come to analyse their own students' learning, and from this develop their teaching.

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Paper II

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RESEARCH REPORT

Reading New Environments: Students' ability to generalise their understanding between different ecosystems

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This paper is based on a study of how students' read nature in different ecosystems. Its focus is on ecology and the context is outdoors. This literacy has to do with an ability to recognise organisms and relate them to material cycling and energy flow in the specific habitat that is to be read. A teaching sequence was designed in order to develop a class of secondary students' ability to read nature in a forest ecosystem. After instruction they were taken to another ecosystem, a pond where they were asked to read the new environment. The main goal was to follow to what extent they can transfer their understanding from one ecosystem to another. The study is based on recorded interviews, field work, and classroom activities, and it shows the importance of learning general patterns in nature and relating them to functional groups of organisms in an ecosystem.

Keywords: *Ecology; Reading nature; Secondary students*

Introduction

This paper reports on a study of ecology teaching to Swedish secondary school students (age 13–14). Students in Sweden are usually introduced to ecology in primary school with examples of food chains and simple models of ecosystems with their constituent plants and animals. In school books for secondary biology several different ecosystems are presented, and the curriculum stresses the knowledge of different ecosystems and their key organisms.

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From an international perspective, ecology is a large component of the biology curriculum and the ecosystem is a central concept in ecology. This was exemplified by Cherrett (1989), who developed a list of the 50 most important ecological concepts by surveying the members of the British Ecological Society, and ecosystems was ranked number one by the majority. Most teachers today would probably agree with Cherrett's list and consider ecosystems as a fundamental part of the biological course content. But how can we teach about different ecosystems in a fruitful way? In an earlier study on student-teachers' views of the most important learning situations during an ecology course we found that field work, and excursions to different ecosystems, were considered very important by the students (Magntorn & Helldén, 2003). But the current situation in many schools, not only in Sweden, does not allow for much field study for various reasons, and certainly not for excursions to many different ecosystems (Barker, Slingsby, & Tilling, 2002). We see it as problematic for the teachers when, on the one hand, the curriculum stresses the importance of knowing different ecosystems and students stress the importance of excursions, and yet on the other hand the possibilities for studying the ecosystems outdoors often are very limited.

The purpose of this study was therefore to focus on one ecosystem and investigate students' ability to generalise the knowledge of this ecosystem, studied in detail, to other ecosystems. In our study the chosen ecosystem for our teaching sequence was a forest and the ecosystem chosen for investigating the ability to generalise the knowledge was a pond. A teaching intervention to fit within the existing biology curriculum was designed. The approach was top down, starting with the abstract phenomena of energy transfer and photosynthesis and respiration. This was discussed and illustrated by models and metaphors in the classroom. From this starting point we wanted to add the field experiences of investigating the organisms and the non-biological factors visible in the forest. Since we are aware of the problems students have in grasping the abstract phenomena we wanted to make sure these were discussed with the students early and repeated throughout the course.

Research Questions

The following research question was developed to guide our data collection and our analysis:

- What are the characteristics of the students' expressed ecological understanding of the terrestrial ecosystem before and after instruction?

This information about students' level of understanding of general ecology together with the knowledge about the terrestrial ecosystem is necessary in order to answer the second and central question in this project:

- To what extent can the students apply their understanding in order to "read nature" in the aquatic ecosystem after studying the ecology of a terrestrial ecosystem?

Reading Nature

The ability to read nature is central in this work and has been described in another paper (Magntorn & Helldén, 2005) but needs a brief explanation here as well. We see it as an important aspect of ecological literacy, where ecology is seen as a scientific field with a tendency to amalgamate with other disciplines and form interdisciplinary fields such as environmental education. The phrase ecological literacy is a re-conceptualisation of the phrase *environmental literacy*, which Orr (1992) refined to *ecological literacy*. Orr does not identify any differences between the phrases and uses them interchangeably (Cutter-Mackenzie & Smith, 2003). According to Orr (1992) ecological literacy primarily constitutes "knowing, caring and practical competence". Orr further implies that ecological literacy encompasses an understanding of "how people and societies relate to each other and to natural systems, and how they might do so sustainably" (p. 92). In other words, knowing how the world works and the dynamics of environmental crisis, and thus knowing how to preserve and maintain the environment. Ecological literacy is ideally about developing a rich knowledge base and multifaceted beliefs and/or philosophies about the environment that lead to ecological sustainability. Returning to our phrase reading nature, we see this ability as an important aspect of ecological literacy. Its focus is on ecology and the context is outdoors. This literacy has to do with an ability to recognise organisms and relate them to material cycling and energy flow in the specific habitat that is to be read. It has to do with authenticity where the natural world that we face outside is the book to be read and the tools we have are our experiences from previous learning situations both indoors and outdoors.

Research Review

Literature concerning secondary students' explanations and understanding of ecology, and in particular a systems focus on ecology, was reviewed. This body of literature suggests that students do not have a good grasp of the complexity in food webs, of energy flow or of the dynamics and structure of ecosystems (Adeniyi, 1985; Gallegos, Jerezano, & Flores, 1994; Grotzer & Basca, 2003; Hogan & Fisherkeller, 1996; Leach, Driver, Scott, & Wood-Robinson, 1996). If we start with photosynthesis and respiration, the first is understood in many ways. A commonly held (Aristotelian) idea is that plants get their "food" from the soil (Carlsson, 2002; Helldén, 2004; Wood-Robinson, 1991). The process of respiration, particularly in plants, is completely unknown to a majority of students (Helldén, 2004; Leach et al., 1996). In this project we are not only interested in how they understand the isolated phenomena but more in their ability to relate the phenomena in the natural context and to link the parts to a whole (i.e., to use systems thinking). In a review by Perkins and Grotzer (2000) it is claimed that understanding and reasoning effectively about ecosystems involves comprehending a variety of causal patterns in nature, for instance domino-like, cyclic, or reciprocal patterns between the organisms as well as between organisms and the abiotic components. Without a grasp of the behaviour of such patterns, students are likely to impose a simple linear form to organise new information. In such a simple linear form there is typically one cause and one effect with a direct and unidirectional relationship. In contrast, domino causality describes a causal pattern where effects propagate out from causes in domino-like patterns that can be branching as well as linear. As an example, the energy flow in a food web follows a linear domino-like pattern involving all the organisms. Leach et al. (1996) showed that students have difficulties differentiating between energy and matter in ecosystems. Ideas of consumption of energy are commonly held and the transformation of matter is not commonly understood (Carlsson, 2002; Leach et al., 1996; Watson & Dillon, 1996).

By studying an ecosystem and building the examples and the theories around what we see in this ecosystem we hope to reduce another problem that has been shown in ecology education; namely, that the students loose interest since they are not familiar with the organisms or the examples given in ecological textbooks (Magro, Simmoneaux, Navarre, & Hemptinne, 2001). As Slingsby and Barker (2003) claim, the nature of scientific enquiry is to make contact between abstraction and reality and to start from observations of the "real world". As a consequence of this, a substantial part of the teaching and the collection of research data has taken place outdoors

Basic Assumptions

In this study we are interested in students learning and transfer of knowledge. A useful instrument for us has been Ausubel's theory of meaningful learning (Ausubel, 1978) supplemented by Novak (1998), who stresses the importance of the interplay taking place between emotions, personal relevance, and context when people learn. The one who is learning is actively extending his/her existing concepts or defining new ones. This also means finding new connections between those already given and the new ones, as well as finding new structures and sustainable theories. When meaningful learning occurs, the relationship between concepts become more explicit, more precise, and better integrated with other concepts and propositions. This involves what Ausubel calls *progressive differentiation* of conceptual and propositional meanings, resulting in more precise and/or more elaborate ideas. In our study, a relevant example might be the understanding of the growth of plants developing from being restricted to soil, water, and sun, to after instruction also including molecules in the air.

The design of the study mirrors some basic assumptions regarding ecology education held by the researchers. First, we believe in the importance of field work where the first hand experiences in authentic environments are paramount. This is supported by Rickinson et al. (2004, p. 24) saying that:

> fieldwork can have a positive impact on long term memory, due to the memorable nature of the fieldwork setting and there can be reinforcement between the affective and the cognitive, with each informing the other and providing a bridge to higher order learning.

In this study we are not making any comparative judgements about different teaching strategies, but we want to emphasise this clear point of view that has influenced the teaching design. Second, we wanted to start from a top-down perspective where the abstract phenomena of energy flow and cycles of matter were discussed and illustrated in the classroom. From this starting point we wanted to add the field experiences of investigating the organisms and the non-biological factors visible in the forest. Since we are aware of the problems students have in grasping the abstract phenomena, we wanted to make sure these were discussed with the students early and repeated throughout the course.

Based on our experiences as biology teachers, together with the epistemological view and the findings from educational research already presented, we have designed the teaching sequence.

The process of transfer is central in this study. The first factor that influences successful transfer is the degree of mastery of the original ability. Without an adequate level of initial learning, transfer cannot be expected. It is therefore highly relevant to follow the students' learning and evaluate their ability to read nature after instruction. Research has indicated that transfer across contexts is especially difficult when a subject is taught only in a single context rather than in multiple contexts. When a subject is taught in multiple contexts, however, and includes examples that demonstrate wide applications of what is being taught, students are more likely to abstract the relevant features of concepts and to develop a flexible representation of knowledge (Bransford, Brown, & Cocking, 1999). The multiple contexts in this study can be regarded as the combination of indoor and outdoor instruction as well as the variation of methods both for instruction and evaluation of students understanding. Studies also show that abstracted representations do not remain as isolated instances of events, but become components of larger, related events—schemata. Knowledge representations are built up through many opportunities for observing similarities and differences across diverse events. Schemata are posited as particularly important guides to complex thinking, including analogical reasoning: Successful analogical transfer leads to the induction of general schema for the solved problems that can be applied to a subsequent problem (e.g., the general understanding of the cycling of matter and flow of energy in an ecosystem might be applied to another ecosystem). Memory retrieval and transfer are promoted by schemata because they derive from a broader scope of related instances than single learning experience (Singley & Anderson in Bransford et al., 1999; National Research Council, 1999; Novick & Holyoak, 1991). Can we find transferable schemata helping students to read nature between different ecosystems?

Teaching Sequence and Data Collection in Outline

The teaching was carried out in a Swedish Year 7 class of 23 students aged 13–14. Due to the lack of sufficient research data from some students, 15 students (seven boys and eight girls) are presented in this study. The school is a public school in a middle-class community and the 15 students ranged from high to low achieving. Having identified learning aims and general teaching approaches we shall describe the teaching approaches more in detail as well as our different roles in this project as teachers and researchers. It is important to say that the instruction was conducted by the ordinary class teacher, an experienced secondary science teacher. She also supervised students' construction of concept maps. All the interviews and collaborative field work were supervised by the researchers. Planning of the teaching involved both the design of instructional activities and consultation with the teacher about the implementation of these activities. There was continuous negotiation between the researchers and the teacher about the content and the design of the teaching sequence. The forest, where all the outdoor teaching took place, is a pine and oak forest close to the school. The overall teaching sequence comprised four phases spanning seven lessons of varied duration from 60 to 200 min (see Figure 1). In all, the teaching was considered equivalent in time to what the teacher normally spent on this part of the biology curriculum.

The rich data from this study come from interviews, concept maps, and records of collaborative field work. Before and after instruction each student was interviewed about the terrestrial ecosystem, and as part of the teaching sequence students made three individual concept maps on photosynthesis, energy, and a final map on the forest ecosystem. Students also collaborated in small groups where they constructed a miniature ecosystem in a plastic aquarium. This was done both in the forest and by the pond. The transfer interview was conducted by the pond. Interviews 1 and 2 were designed to illustrate students' original and developed ability to read nature. Interview 3 had a slightly different design aiming at eliciting students' ability to generalise between the ecosystems.

The sequence of teaching and data collection is illustrated in Figure 1. The teaching sequence with its different themes is broadly described next, followed by a short summary of the data collection conducted in the different phases of the teaching sequence. Important to note is that the issue of this paper is not to address the role

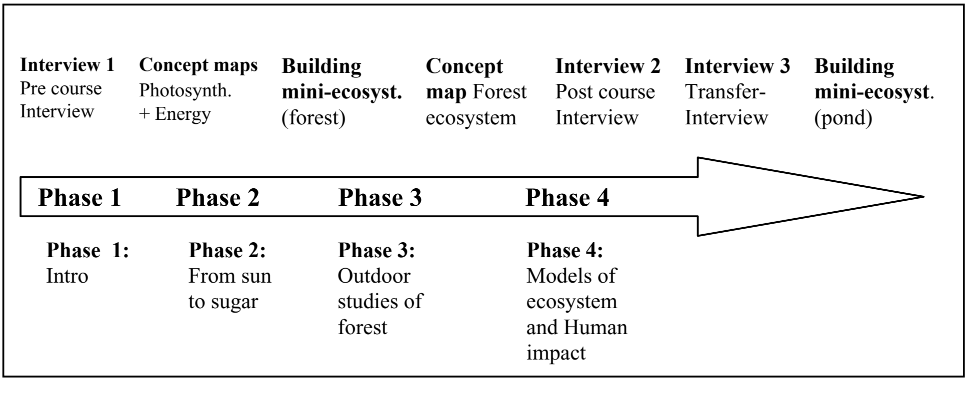

Figure 1. The teaching and collecting of data in outline. Along the arrow indicating a time line, the instances for data collection are indicated above, and the text below indicates the teaching sequence during the course. Interview 1 was conducted prior to instruction. Interview 2 was conducted after instruction, and Interview 3 was the transfer interview conducted after instruction in another ecosystem

of the teacher and her ability to encourage the students to be metacognitive or to scaffold their learning; it is rather to describe the content of the teaching sequence and the individual learning outcome based on our collected data.

Phase 1: Introduction

The teacher introduced the theoretical field of ecology, and the idea of concept maps was presented by one of the researchers. Students practiced making concept maps with an emphasis on their hierarchical structure and the importance of the linking words. Prior to instruction, each student was interviewed in order for us to study their ability to *read nature* and their knowledge of basic ecology. The interviews lasted for approximately 20 min and they were conducted in a terrestrial ecosystem close to school. The interviews were semi-structured and initially the students were asked to describe the natural environment and explain what they could recognise and why they thought it looked the way it did.

Phase 2: Top-down perspective from sun to sugar

Lessons 2 and 3 were designed to enable students to recognise the importance of energy as a driving force in any ecosystem and photosynthesis as the process that makes the solar energy available as chemical energy in ecosystems. The teacher used energy cards to illustrate the flow of energy. These cards picture items such as the sun, plants, and humans (see Figure 2). Students arranged the cards in sequences to illustrate their view of the energy flow in an ecosystem. The main point is to show the sun and photosynthesis as the starting point in any of the energy flows. In order to challenge students' predominant idea of plants growing from sun, soil, and water, the teacher discussed van Helmonts' classical experiment from the seventeenth century, showing that the biomass of a growing plant only minimally originates from the soil. The formulae for respiration and photosynthesis was introduced using LEGO© pieces of different colours representing carbon, oxygen, and hydrogen atoms. The main purpose was to illustrate that we have the same building blocks (i.e., atoms) in building carbohydrates and oxygen gas as we have in the products from respiration, carbon dioxide and water. Students tinkered with running photosynthesis backwards and forward using the LEGO© pieces. A sealed ecosystem with

Figure 2. The energy cards in a sequence starting with the sun and ending with an illustration of an experiment conducted with students in Styrofoam boxes illustrating how the chemical energy is transformed to heat by respiration. The heat is measured by thermometers in the lid of the box

a plant rooted in soil in a closed glass jar was discussed with a focus on the cycles of water and carbon.

After Phase 2 the students made their own concept map on energy and photosynthesis in an ecological context. The task was for students to come up with relevant concepts, organise them, and link them together with appropriate labels. After completion of the concept map each student explained the design of their maps to one of the researchers. This discussion was audio-taped.

Phase 3: Outdoor studies of biological and abiotic factors in the forest

In Lesson 4 the forest was introduced. The non-biological factors influencing the plants in the forest were studied with a focus on the importance of the soil and the light conditions. The dominant species in the tree, shrub, and herbaceous layer were examined and their ecology was discussed together with the general role of the plants as both food and oxygen producers. In Lesson 5, animals were collected, identified and their ecological roles were discussed together with their distribution and abundance. As an example of the energy flow in the ecosystem the teacher drew on the autecology of the goldcrest (*Regulus regulus*), the smallest bird in Sweden, weighing about 6 g. On a very cold day it has to eat up to six times its own weight. All students collected goldcrest food (spiders, springtails, and other insects on the branches of the coniferous trees). The number of arthropods was calculated and the amount of time a goldcrest would be able to survive from this was estimated.

As a final task in Phase 3, students built a sealed mini-forest that would survive for at least 6 months. The activity took place in the forest in groups of three, and the students had to collect material that they considered necessary. They made a list of what to put in the container and explained their choices. The activity and the discussion between the students when making this sealed ecosystem was video-taped and audio-taped.

Phase 4: Linking practical experiences to theories of ecosystems

In Lesson 6 the aim was to help students understand how the living components in the ecosystem interacted. We started with collecting invertebrates in the forest, and looked for traces of larger animals such as eaten cones and faeces. Animals were sorted into functional groups and they were identified from simple keys. The students drew food pyramids where they inserted their own drawings or copied pictures from field guides of the animals and plants found in the forest. The autecology of some key organisms and the morphology of the organisms as a key to distinguishing their ecological roles were discussed. Important features such as the relative size of eyes and of mouth parts together with the movements of the animal were related to the feeding strategies of the animals. Lesson 7 was an excursion to the forest and its surroundings. The aim was to summarise the course and to discuss succession, disturbance, and the human impact on this ecosystem. In small groups they also carried out role-plays illustrating possible life histories of a carbon atom in the forest.

The construction of the mini-forest was discussed during the next lesson. As a follow-up to the lessons about plants and animals in the forest, and the models of food chains and food pyramids (Lessons 5 + 6), students made an individual concept maps to portray the forest ecosystem. The students came up with the concepts themselves, except for the following three that were compulsory: *energy*, *food pyramid*, and *human impact*. Post-course interviews on the students' ability to read the terrestrial ecosystem were carried out using the same interview format as in Interview 1.

Phase 5: Follow-up activities in early September, 3 months after the course finished

In order to find out to what extent the students can transfer knowledge about the forest ecosystem to another context we performed a post-course interview. Each student was taken to a pond a few kilometres from the school. Surprisingly, none of the students had ever been to this pond before. The students were asked to observe the ecosystem visually and to collect animals and plants from the pond. While they were doing this they were asked to describe and compare the similarities and differences between the pond and the forest ecosystems. The discussions were audio-taped.

A week after the interview students built a mini-lake under the same premises as in the forest. This has been audio-taped and video-recorded.

Results and analysis of Interviews 1 and 2

The interviews focused on the following topics: photosynthesis and decomposition, the cycling of matter, and the relations and causality between functional groups in the ecosystem. We also focused on student's views on the ongoing processes or dynamics, such as succession and human influence, on the landscape both in a short-term and a long-term perspective, and on students' views of the organisms in the ecosystem, their naming, and their ecological roles. These topics we consider important components of the ability to read nature, which is our theoretical lens for analysis. The questions in the interview schedule were open ended. The aim was to illustrate students' conceptual understanding in the outdoor context. The first stage of analysis involved the development of a coding scheme for each topic. This was achieved by reviewing students' responses and identifying common ideas and modes of explanation. The coding was developed from student's responses rather than being based on, for example, the normative science perspective. The researchers have jointly studied the data in order to define a limited number of categories for each topic covering the scope of responses. Each student could only score at one level in each topic, and the scoring was independently made by the two researchers and negotiated until consensus was reached.

In our group of 15 students ranging from high to low achievers and with different levels of motivation and prior understanding, there, of course, will be 15 individual learning trajectories. The score for each topic is presented in Figures 3–7 and the total score of each student is presented in the Appendix. We have chosen to illustrate important aspects of reading nature by presenting draw out themes from the data of the following three students; Student A, Hugh, is considered to be high achieving, and already in the first interview he related to his prior experiences from observations and studies of nature. Fredric (Student L), on the other hand, initially had a limited understanding of the important components of ecology. He had little experiences of being outdoors in nature but is equipped with a growing interest for science and nature studies. Alice (Student J) is a highly motivated student, but rather low achieving. She has some earlier experience from being outdoors with family and friends.

Photosynthesis, Decomposition, and Cycles of Matter

Photosynthesis. Comments on Figure 3. The main questions are: How do you think the plants are living here? and What do they need to survive?

As expected regarding results from other studies (e.g., Leach et al., 1996), the dominating answer from Interview 1 is that food is seen as something that plants take in from the environment and not as being synthesised within the plant. Hugh says in the first interview:

> I think plants take up the nutrients from the soil and yes they need water too. And those with leaves I think the plants with leaves can make oxygen if they get some sun but I don't know if all plants do that, I think only those with leaves. Not those dry plants there. (Hugh, Category 3)

Three students said that they thought plants "live from food, like we do", but on follow-up questions none of the three were certain about this statement and it might reveal a spontaneous answer rather than a reflected one (Welzel & Roth, 1998). Most of the students, including Alice and Fredric, said in the first interview that the necessities for plant survival are sun, water, and soil, echoing the outcome of

Categories on photosynthesis	Interview I	Interview 2
1. Plants live like us. Eat plants and animals.	3	
2. Plants need sun, water and nutrients.	9	3
3. Plants need sun, water and nutrients and produce food and /or oxygen.	2	3
4. Plants need sun, air (CO2)and water and they make sugar and/or oxygen.	1	9
Total	15	15

Figure 3. Photosynthesis. The number of students belonging to each category in Interviews 1 and 2. Each student can only score at one level in any interview and the total sample is 15 students

Categories on decomposition and cycles in nature	Interview I	Interview II
1. Plants are decomposed without agents* as a natural process No explanation or end product described: No cycles mentioned.	2	-
2. Plants are decomposed by agents* and turned to soil. No cycles mentioned	4	1
3. Plants are decomposed by agents* and turned to soil. Soil is cycled.	9	6
4. Plants are decomposed by agents* and turned into free nutrients (+ CO_2). Uncertain about what is cycled- energy or nutrients or both.	-	8
Total	15	15

* (agents are different decomposers mentioned by the students)

Figure 4. Decomposition and cycles in nature. The number of students belonging to each category in Interviews 1 and 2. Each student can only score at one level in any interview and the total sample is 15 students

numerous similar studies. In the second interview most students have added oxygen as a product and air or carbon dioxide as needs for the process, both in concept maps and interviews. This shows that most students, including Hugh, Alice, and Fredric, can describe the basic process in a correct way, bearing in mind, however, that answering this question correctly does not necessarily reveal a meaningful understanding (Ausubel, 2000) of the concept.

Decomposition and cycles in nature. The two main questions are: Tell me what you think will happen to all the plants you can see here when they die? and We often talk about cycles in nature, what kind of cycles do you think these plants are involved in now?

Students often find decomposition more intuitive than photosynthesis, and it often has to do with students' hands-on experience of the process (Helldén, 1995; Hogan & Fisherkeller, 1996; Wood-Robinson, 1994). Many students spoke of experiences of worms in compost, and in the second interview they related both to worms and wood lice when describing the process. What they often said is that plants are turned into soil and Hugh (Category 3) is an example of this when he also involves the cycling of the soil.

> They eee I believe they are decomposed after a while and they turn to new soil for new plants which grow next spring eee it is worms that eat the plants and turn them to soil and then the plants takes that soil up again which will be food for the worms like a cycle. Anyway the plants take nutrients in the soil and plants are needed all the time to produce new soil. (Hugh, Interview 1)

After the course most students, including Alice and Fredric, describe the process according to Category 3, but Hugh and four other students describe nutrients and carbon dioxide as a product from decomposition. Decomposition can be considered a linchpin concept in ecology (Hogan & Fisherkeller, 1996), helping students to realise the cycling of matter in nature. Our results indicate that students are often satisfied with a cycle where decomposers and plants are involved in a nutrient cycling or soil cycling without involving respiration with carbon dioxide and water, leaving the process far from accurate. When students say that it was either energy or sugar being cycled, it could be a possible effect of the discussions about energy cards and Van Helmonts' experiment showing that plants only need little nutrients as food.

Generally we see a significant development over the course both in the interviews and concept maps, but meaningful understanding of the relation between photosynthesis, decomposition, and carbon cycling on a molecular level does not seem to be clear for more than a few of the students.

Dynamics, Causality, and Relations between Organisms and Abiotic Factors in the Ecosystem

Dynamics of the ecosystem. The main question was What do you think this ecosystem would look like if you came here in 60 years showing your grandchildren this place? Many students both in the first and second interview expressed limited understanding of the ongoing changes in landscapes both on a small and larger scale. The changes we refer to can be natural such as succession, but also of anthropogenic origin where human activities have an impact on the landscape.

The majority of the students, including Alice and Fredric, did not believe the landscape would change at all, whereas six students were hesitant about changes but expressed an understanding that gradual changes normally took place in ecosystems, but they did not mention the human impact (Category 2). Only Hugh in the first interview expressed the idea that ecosystems are not stable and do change over time, and that "humans normally have an impact even in forests like this" This understanding of the normal ongoing changes in our "natural environments" has proven to be very difficult for young people to grasp (Weins & Moss, 2005). Yet we see the history of a landscape as an important component for reading nature. Prior to the second interview, natural succession and human impact were discussed during the teaching sequence and exemplified by field discussion about the planted pine

Categories on dynamics in ecosystems	**Interview I**	**Interview II**
1. Nothing in the landscape changes over time.	8	4
2. Gradual change over time is possible and likely to happen.	6	5
3. Constant changes occurr due to natural succession and human impact.	1	6
Total	15	15

Figure 5. Dynamics in the ecosystem. The number of students belonging to each category in Interviews 1 and 2. Each student can only score at one level in any interview and the total sample is 15 students

trees being out competed by deciduous bushes and trees. Four students, including Alice, still express that the landscape is static: "I think it would be the same. If you want to change nature you have to plant trees or so, otherwise it doesn't change" (Alice). Five students, including Fredric, stated that gradual changes were natural, but they all had difficulties when asked to describe future changes of this environment, and six students mentioned both the natural succession and the human impact by plantation of trees having taken place in the ecosystem and how it influences the forest in the future.

Causality in the ecosystem. This topic has to do with student's views on causal interactions between different organisms they see or they know of in the ecosystem and how these interactions can be described by models such as food chains or food webs in this ecosystem. The scoring system was designed based upon certain patterns of responses expected according to earlier research (e.g., Grotzer & Basca, 2003). The interview questions were: What organisms are needed in this ecosystem? and How are they related?.

One-step linear causality is connections between populations that focus only on a predatory–prey relationship in a one step unidirectional fashion. Cyclic causality involves an iterative pattern, for instance decomposition. Mutual causality is when two populations impact each other; for example, Hugh states that the snails and plants are mutually related since "plants are food for snails and snails release necessary nutrients back to plants. are necessary for the plants".

In the first interview, nine students, including Alice and Fredric, expressed a linear view with only single-step relations, with one population directly affecting another (e.g., plants are eaten by herbivores, which are eaten by carnivores). Five students express a cyclical view including the same trophic levels as in Category 1 but also adding the decomposers that seem to trigger their ideas of the cyclicity in the ecosystem. In the second interview all students have a cyclical view of the causality, but 10 students, including Alice and Fredric, still have a simple model of organisms only relating to those one step below and above in a food chain (Category 2).

Categories on causality in ecosystems	**Interview I**	**Interview II**
1. Uni-directional linear causality with one population directly effecting another.	9	-
2. Uni-directional cyclic causality with one population directly effecting another.	5	10
3. Domino causality with uni-directional causality branching and involving many populations.	1	4
4. Mutual causality with feed-back loops and cyclic pattern.	-	1
Total	15	15

Figure 6. Causality in the ecosystem. The number of students belonging to each category in Interviews 1 and 2. Each student can only score at one level in any interview and the total sample is 15 students

This is not surprising in the light of Webb and Boltt (1990) showing that students at upper secondary and high school level often believe that a change in one population will only affect another population if the two are directly related. Many of the students refer to a food pyramid, which is a model we worked with, but they did only make single-step relations and discussed the cycling despite the linear appearance of the pyramid model. In Category 3 students express a cyclical model where the feeding strategies can branch off in different directions, leading to a food web model where populations are indirectly related. This was explained by four of the students in the second interview and by Hugh already in the first interview. Recognising domino causality includes, for instance, that the disappearance of green plants would affect not only the animals eating green plants, but also the secondary consumers eating those that eat green plants. In the second interview Hugh gives a description of how populations on different trophic levels relate by feedback loops and that they can be mutually dependent, where "The plants are then taking up the nutrients again and either decomposers or plant eaters eat them before it starts again and they need each other" (Category 4).

Recognition of organisms and relating them to functional groups. The main question was: Can you recognise any of the living organisms and tell me what you think their functions are?

In the first interview all 15 students relate to plants as food, and animals as eating the plants or eating other animals. The only species mentioned were the pine trees, and organisms were classified as birds, insects, and flowers. These limited knowledge is not surprising according to studies of Bebbington (2005) and Pickering (2003), showing that species knowledge generally is in decline. In the second interview, 10 students could name the most common plants and trees, they recognised a larger number of organisms, and most students could identify the animals as representing different functional groups such as decomposers or predators. Four students still

Categories on recognition of organisms in the ecosystem	Interview I	Interview II
1.Very limited or no species knowledge. Recognises plants as food and animals as eating plants or eating other animals.	15	4
2. Recognise species of plants and animals and refer them to producers, herbivores and carnivores.	-	2
3. Recognise species and refer them to functional groups as in category 2 but also including decomposers.	-	5
4. Recognise species and refer them to functional groups as in category 3 and relate their function and abundance to a model of a food pyramid.	-	4
Total	15	15

Figure 7. Recognition of organisms. The number of students belonging to each category in Interviews 1 and 2. Each student can only score at one level in any interview and the total sample is 15 students

belonged to Category 1 and were showing little interest in taxonomy. Two students (including Alice) recognised species of plants, herbivores, and carnivores, and they related them to functional groups. Five students also added decomposers to the list of functional groups and they referred to them both by identifying them (e.g., woodlice and earthworms) and recognising their important functions in the ecosystem (Category 3). Hugh and Fredric and two other students, also describe the relation between the organisms according to a model of a food pyramid (Category 4). Fredric says in the second interview "There must be most plants because they are the energy source for all. And then many plant eaters but not so many predators because then the food would not last for all". Beside the conceptual knowledge already illustrated, it is also worth mentioning that in the second interview, as different from the first, most students were actively looking for organisms and they described the vegetation in relation to the tree–brush–field and bottom layer, showing that they had developed their ability to study and describe nature.

Concept maps as a complement to the interviews regarding cycles and flow

Concept mapping with its graphical structure has been recognised as a powerful tool for helping students understand the notion of complex models such as ecosystems (Kinchin, 2000), and research has shown the importance of getting acquainted with the concept maps in order to make them a useful metacognitive tool for the learning pupil (Novak, 1993). Experience in using hierarchically constructed maps in science education shows that the maps were more successfully utilised as the student's experience in drawing these maps grew (Novak, 1998; Novak & Gowin, 1984). In our study several concept maps were made (see Figure 1), and the fourth map, describing the forest, has been analysed in detail as a complement to the interview data from Interview 2.

As described earlier in relation to cycles, students have difficulties in discriminating *what* is cycled. Students often describe the processes in the ecosystem as "something is cycled" but they cannot explain what is cycled. No student seems to grasp the differences between the linearity of the energy flow through the system and the cyclicity of matter. The top-down approach of instruction stresses these processes and they were presented early and repeated throughout the course. We therefore found it relevant to illustrate the difficulties students have with this discrimination by presenting excerpts from Alice's and Hugh's concept maps. We have selected a part of Alice's and Hugh's concept maps to illustrate how one student, Alice, does not describe any cyclicity, but relates to energy as introduced from the sun and propagating to animals via plants. Hugh, on the other hand, describes cyclicity of matter but he also includes energy in the cycle.

Comments to Alice's Concept Map (Figure 8)

Photosynthesis is described on a molecular level but Alice does not relate oxygen to the reaction. There is no cyclic causality between producers and consumers, and no

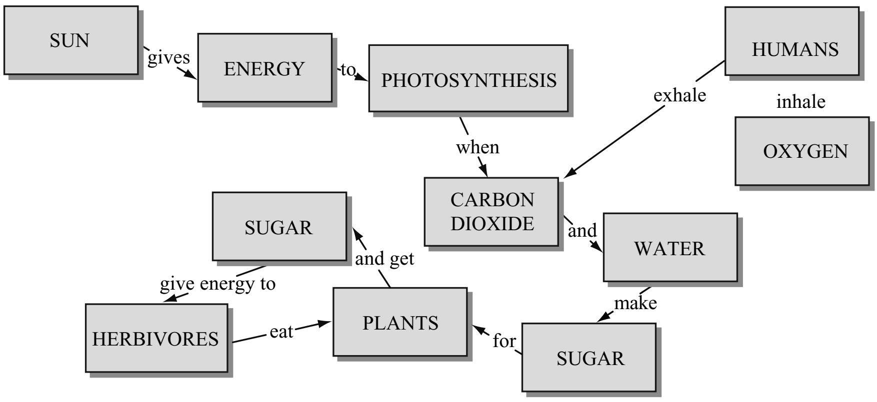

Figure 8. Alice's concept map. This is an excerpt from a larger concept map illustrating the forest ecosystem. She made it in Phase 4 (see Figure 1) after the last teaching intervention in the class

correlation between photosynthesis and respiration. Energy is described as being given from the sun and taken by the herbivores in the form of sugar in what we analyse as a linear way. But in the lower part of her concept map, outside this excerpt, she illustrates a cycle of sugar where the sugar during decomposition is released to the soil and taken up by the roots of the plants. This can be analysed as an alternative conception of how energy in the form of sugar is cycled in the system. Alternative both to the scientific view but also to her conception illustrated in Figure 8.

Comments to Hugh's Concept Map (Figure 9)

Hugh describes a cyclic causality between plants and animals involving carbon dioxide, water, and oxygen. He expresses the idea that sugar is cycled and that it is related to energy. Hugh also mentions that nutrients and energy are cycled. In Hugh's concept map we can see the cycle of nutrients from the decomposers and the cycle of carbon from the exhaling animals. The differentiation between the linear flow of energy and the cyclic flow of matter is confused. He regards sugar as energy, and this is emphasised by the concept *energy package*, mentioned by the teacher as a metaphor for the glucose, which Hugh together with several other students use in their explanations. Matter and energy becomes one unit that is cycled in the ecosystem.

Exemplifying the Differences in Three Students' Ability to Read Nature Before and After Instruction in Relation to Research Question 1

We have chosen the students Hugh (Student A), Fredric (Student L), and Alice (Student J). They are more familiar to the reader by now since we have followed

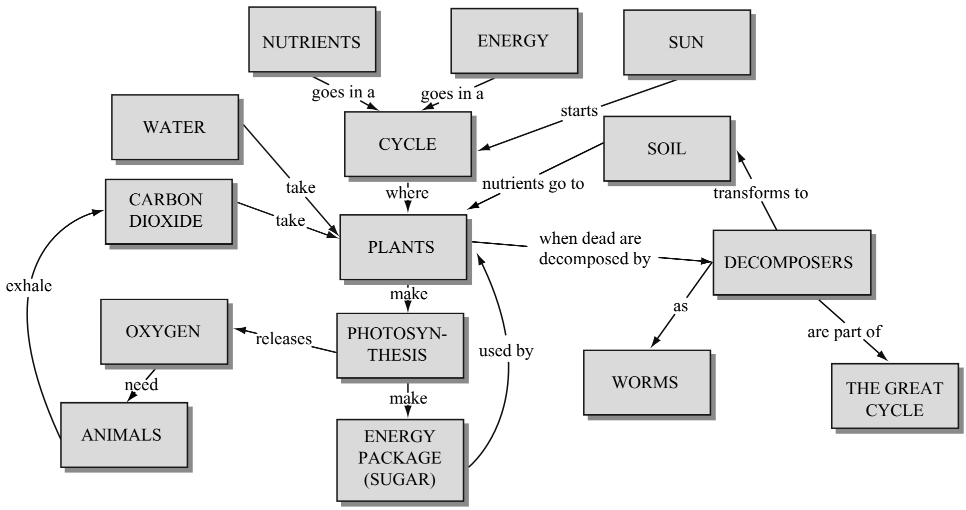

Figure 9. Hugh's concept map. This is an excerpt from a larger concept map illustrating the forest ecosystem. He made it in Phase 4 (see Figure 1) after the last teaching intervention in the class

them through the analysis. In Figure 10, the two bars per student illustrate the scores from Interviews 1 and 2, and the scores are related to the five topics in the chart. Generally all 15 students developed their ability to read nature and each student's development can be followed in the Appendix. Hugh showed a high level of understanding in all the different topics already in the first interview. The only exception to this is the knowledge of organisms, which was low but developed strongly over the course. Fredric, on the other hand, initially had a limited understanding of the important components of ecology. He developed his understanding in basically every category, especially in the function of organisms. Alice did not develop very much during the course and she had problems relating the details to the whole and also to describe the processes on a molecular level. In the first interview she described the structures and processes on a macro level, saying that there have to be plants and animals, but the reasons for this and the understanding of causality in the system are limited and do not develop very much during the course.

All three students develop their ability to recognise organisms and relate them to functional groups. They develop their understanding of cycles and of photosynthesis, whereas their understanding of decomposition does not develop but is already initially relatively elaborate. Very few students in both interviews express an understanding of the landscape forming processes, both of anthropogenic and natural origin. Understanding of causality and the interrelations between populations have developed from often being linear with single-step relations to being cyclic and involving different trophic levels.

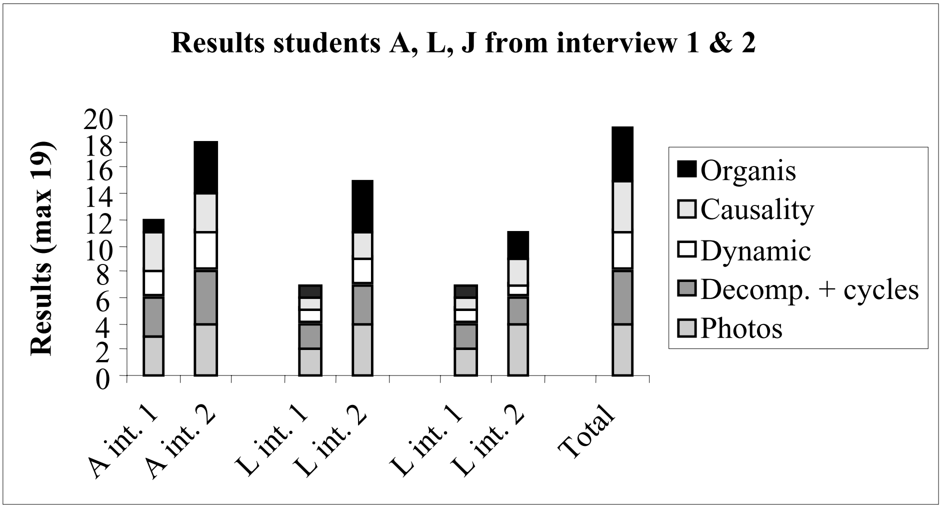

Figure 10. Illustration of how Students, A, L, and J have developed their ability to read nature in the terrestrial ecosystem over the course. For each student there are two bars, indicating the level of understanding of the different topics from Interviews 1 and 2. The score on each topic is related to the categories where more advanced answers give a higher category = higher score. Dynamics have a maximum score of 3 and the other topics have a maximum score of 4. The maximum total score is 19

Having analysed student ideas and the ability to read nature in relation to six relevant topics, we are now ready to move from the first research question, about students learning, to the second question, which is central in this work and deals with how students can transfer their ability to read nature to the new ecosystem. We refer again to schemata and their importance for high-level cognition because once they have been acquired they can be applied to a variety of subsequent problems (Hummel & Holyoak, 1997; National Research Council, 1999; Singley & Andersson, 1989). So the question is what components of the ability to read nature can the students transfer and can we consider them schemata promoting transfer since they derive from a broad scope of related instances?

Interview 3: Transfer interview

We have chosen an aquatic ecosystem since we believe this will challenge students' ecological understanding and therefore illustrate their ability to *read nature* in a better way than if we had asked them to read another terrestrial ecosystem. We are aware of the difficulties students in this study, as well as in other studies, have with the gaseous phases of photosynthesis and respiration, which is likely to be yet more complicated to relate to in an aquatic environment. Another challenge is that freshwater organisms often are not so well known (Anderson & Moss, 1993), and this particular class had no prior school experience in studying freshwater ecosystems.

The transfer analysis is based on individual interviews and student group discussions when constructing mini-ponds in plastic aquariums. The interviews and field activities were recorded in September, 3 months after the course finished.

Interview Design and Analysis System

Scientific understanding frequently involves comprehending a system at an abstract rather than a superficial level. Transcending superficial appearances to extract deep principles, or schemata is as critical to science as it is difficult to achieve (Goldstone & Sakamoto, 2003). In the transfer interview we want to study students' ideas of the relationship between abstract principles and superficial structures when they are trying to read the new environment. In comparison with the first two interviews, which were designed to elicit students' developed ability to read nature in relation to the teaching sequence, the transfer interview has a slightly different focus and therefore a different design. The focus is metacognitive on how students can relate between the structural and the systems level and how they can relate back to what they know about the terrestrial ecosystem. This requires an interview schedule that permits a comparison between the ecosystems and that opens up for a broad discussion of the ecosystem without explicitly asking for specific concepts or relationships. Students were asked to make comparisons between the terrestrial and the new aquatic ecosystem, and the questions, being less specific, still opened up for students to reason about cycles and processes such as photosynthesis and decomposition and about the causality and dynamics of the ecosystem and its components. Making sense of a complex system is a difficult task because it requires thinking on both abstract and concrete levels. There are several alternative ways of making sense of such systems, what Collins and Ferguson (1993) have termed "epistemic forms". For example one might look at complex systems from the perspective of a system dynamic model, aggregate behaviour or Structure–Behaviour–Function (SBF) analysis.

SBF Analysis of Students' Ability to Read Nature in the New Environment

We want to analyse how students make sense of the new ecosystem and whether we can find possible schemata or chunks of knowledge that students transfer between different ecosystems. In order to be able to break down data from interviews and field activities into manageable units we have chosen to use a SBF analysis. In a study of experts' compared with novices' understanding of an aquatic system, an aquarium, a SBF-based coding scheme was used by Hmelo-Silver and Green Pfeffer (2004). This framework allows effective reasoning about the functional and causal roles played by structural elements in a system by describing a system's subcomponents, their purpose in the system, and the mechanisms that enable their functions. Their results indicated that novices' representations focused on perceptually available, static structures of the system, whereas experts integrated structural, functional, and behavioural elements. We have found SBF to be a mode of analysis relevant for our purposes since it focuses on causal understanding of the relationship among different aspects of the system. Breaking down students' model of the new ecosystem to these three levels and analysing them separately to see what parts of the structural, behavioural, and functional level students can transfer is our purpose and reason for using the SBF coding to describe the transfer of students ability to read nature.

- **Structures** refer to the elements and physical structures of a system (e.g., trees, mosses, insects, light, and water are some of the elements that comprise an ecosystem).
- **Behaviours** (mechanisms) refer to how the structures of a system achieve their function. These are the mechanisms or interactions that yield a product, outcome, or reaction. They describe the dynamic and often invisible processes that are difficult to represent (e.g., plants turn water and carbon dioxide into carbohydrates and oxygen gas). Behaviour refers to the dynamic mechanisms that cause changes in the structural state of a system.
- **Functions** refer to why an element exists in a given system (e.g., plants produce oxygen and food or worms are decomposers in the forest).

Results and Analysis of the Transfer Interview

The researchers designed an interview schedule with a top-down approach starting in the overview of the ecosystem, finishing with the relations between the organisms in the pond. The first question is designed to elicit students reasoning on structural level. The second and third on behavioural level and the fourth and fifth questions to elicit functional level.

Structure

Question 1: standing overlooking the pond, the main question is: "Look at the pond and tell me what you see and what you think would be similarities and differences between what you see in this ecosystem and the forest we studied last semester?"

The aim of the question is to elicit what the students observe when they look at the pond. Each directly observable object mentioned, such as plants or animals, water, gravel, and light, is considered a structure, but also non-visible objects that students say have to be there such as oxygen or nutrients are structures. Student answers in relation to this question has been categorised by the two researchers independently and negotiated to describe the different levels of structural description among the students (Figure 11).

Four students, including Alice, mention only plants. They say that there is a correlation between plants in the forest and lake:

Categories: Structures in the ecosystem	Interview III
1. Students mention only plants. Correlate between forest and pond e.g., trees are equivalent to reed and mosses and algae are equivalent. Animals and abiotic factors are not mentioned.	4
2. Students mention plants as in category 1 but also include animals and how they correlate between the ecosystems. Abiotic factors are not mentioned.	4
3. Students mention plants and animals as in category 2 but also mention abiotic factors such as nutrients, soil or light.	7
Total	15

Figure 11. Structures in the ecosystem. The students' level of understanding of structure. Each student can only score at one level in any interview and the total sample is 15 students

> I can see a lot of tall grass or reed and that must be like the trees in the forest and the green stuff in the water, those … [pointing at the algae] must be something like the mosses and grass in the forest. (Alice)

In Category 2, four students also mention that there must be animals equivalent to the functional groups in the forest. They mention insects such as dragonflies, and when they see the large number of snails floating on the surface they mention that there must be snails living like snails did in the forest, and also fish, which would be equivalent to larger predators in the forest such as foxes. One example is Eric (Student I):

> Eric: Well, the fauna must be of the same type as in the forest, I mean they have to do the same things but under water.
> Interviewer: Yes, how do you mean?
> Eric: Yes, it is eee a lot of insects and beetles and that kind but they live under the surface and it is basically the same food chain but fish eat the insects instead of gold crests [eating them] in the forest.

Seven students (including Hugh and Fredric) mention plants and animals, but also add abiotic factors such as the water, sun, and air. Three of these students also mentioned that there has to be oxygen in the water for the animals and carbon dioxide for the plants.

An example from this third group:

> I can see all the reeds that are like the trees in the forest and all the small plants, the algae, are like the grass and mosses. But animals are important I don't know their names, some fish and snails and so but there must be the same percentage distribution of herbivores, carnivores and decomposers as in the forest. And light, maybe the plants need more light here and more water. (Fredric)

Analysis. The earlier statement indicates students learning of a concept—the structure of the ecosystem. In the first interview, no student expressed a structured way of studying and describing nature. In the second interview, all students relate what they saw to the functional groups and 10 students had names for several forest organisms belonging to the producers, herbivores, and carnivores. A critical feature constraining the transfer of reading nature seems to be the lack of species knowledge. By the pond the students seem to know what to look for but find it difficult to transfer their knowledge of structures since they do not recognise the organisms by names as they do in the forest. They often express a structure of a general ecosystem. This structure is related to the food pyramid and we consider it to be a schema for several of the students belonging to Categories 2 and 3. Another interesting feature is students' problems with relating to abiotic structures when describing the ecosystem. Abiotic factors were mentioned by 12 of the students in Interview 2 compared with seven in the transfer interview. Non-living structures do not seem so intuitive to include in a description of an ecosystem. This is in line with Eyster and Tashiro (1997), who have shown that high-school students get very confused when they were asked to involve the abiotic components in a food web.

Behaviour

Question 2: "Look at the pond and tell me what you think it will look like if you come back here again with your grandchildren?"

This question is addressing the behaviour of the ecosystem over time where mechanisms, such as succession, change the structures in the ecosystem. All students thought the pond would look the same in the future. Natural succession and human impact was discussed during the teaching sequence and exemplified by field discussion about the planted pine trees being out competed by deciduous bushes and trees. So, the development over the course (see Figure 5) is not surprising, but what might be surprising, even though it is supported by the literature (Weins & Moss, 2005), is that there seems to be no transfer to the new environment. It seems as if their initial thoughts of nature being static again is dominating—as if a pond is always a pond.

Question 3: In preparation for the following questions the students have now hunted organisms in the pond and collected the material in a large tray filled with water. Main question: "Look at the pond and at all the things we have caught. Please try to explain how they all can live together in this pond".

This question is aiming at illustrating how the students can relate biotic and abiotic components in the new ecosystem and how they describe the trophic levels, including the plants, to the cycles of material and flow of energy (Figure 12). Often processes such as photosynthesis or causal relations between organisms as in a food pyramid are examples of a behavioural level of understanding the pond.

This behavioural level is demanding and asks for an understanding of the processes and answers to the often difficult question *how* something behaves. In the transfer interview many students do not relate to this even if they discussed it in the post-course interview. The behavioural level does not seem to be important for many of the students and the avoidance in discussing the behavioural aspects is typical for non-experts (Buckley, 2000).

Categories: Behaviours in the ecosystem	Interview III
1. Students refer to single step behaviour in a food chain where the organisms need energy which they get from the sun (plants) or from eating each other. Students give very few claims relating to mechanisms in the ecosystem.	5
2. Students refer to energy and biomass on each trophic level as the mechanisms for explaining the food pyramid model. Students discuss decomposition cycling of matter and photosynthesis and the problems with the gas phases under water.	8
3. As in category 2 but adding the behaviour of a food web model saying that some organisms are generalists and therefore do not fit the pyramid model.	2
Total	15

Figure 12. Behaviours of the ecosystem. The students' level of understanding of how the structures relate to each other. Each student can only score at one level in any interview and the total sample is 15 students

In the first category five students only refer to single-step relations between the organisms, as in a food chain based on who is eating who in order to get energy. They mention plants as producers of food and/or oxygen but they cannot describe the process (i.e., how it works). They also mention that animals must breathe under water but they do not know how. It simply works; "they live there and they need oxygen so there must be oxygen in the water" (Alice). In Category 2 students refer to the relations between animals as in a food pyramid with reference to energy and biomass on each trophic level. They reflect on the problems with the gas phase and/or the access of nutrients in the water environment, and they discuss the cycling of matter and relate it to the organisms they see.

> Yes, when the decomposers have eaten the plants they become eeh no not soil. Oh, it has to be released in the water directly, the nutrients for the plants because they eee don't have roots these algae. But they need the nutrients and all the other things you know. [He talked about the gases under water earlier in the interview.] (Andrew, Student B)

This indicates a behavioural understanding of the cycling of nutrients but in an aquatic environment that challenges his ideas. Still he can relate back to his experiences of the necessity for nutrient cycling from the forest study. Two students also add the pattern of a food web where the relation of consumers and producers can be very complex and mention that some animals can be generalists. For example:

> Well, because the sugar, yes the energy is lost along the way because they use the energy to move forward and eat and yes it costs to do a lot of things and if it is going to last all the way up to the carnivores there has to be lots of plant eaters or more animals will have to eat both plants and animals. (Hugh, Student A)

Analysis. In Interview 2 a majority of students discussed the behaviour of photosynthesis at a molecular level. Five of these students confused the reaction, and we believe rote learning to be common among many of the students. All 15 students discussed cycles in the ecosystem but six students believed it to be energy being cycled. The higher categories (Grotzer & Basca, 2003) from Interview 2 where students can relate the cyclical models of the matter through the ecosystem as domino-like or mutual between organisms is not present in any of the transfer interviews, but as the following excerpt from one group during their construction of mini-ponds shows, this cyclicity is expressed. It is most often a cyclical single-step model where the processes are less visible and therefore demanding. A general feature that students transfer to the new environment is the idea of cyclicity, either of energy or matter or both.

Function

Question 4: "Tell me what you think is the function of these plants in the pond?"

This question, despite its teleological wording, is aiming at students' ability to realise the importance of sugar and oxygen production in any ecosystem without asking for the mechanisms (i.e., how it works) (Figure 13).

Twelve students (including Hugh, Fredric, and Alice) say that plants produce both food and oxygen in the pond as well as on land.

> I know that they must produce sugar for themselves, the energy package we have talked about. This is food for the others but also more as a by-product is all the oxygen released. I think it must be the same in the water, but I'm not sure. (Fredric)

Analysis. As we have seen from the behaviour level of understanding the chemical processes, students find this difficult and often reveal rote learning where the gases often are mixed up. It is therefore interesting that more students in the transfer interview than in Interview 2 can express the products from photosynthesis and its importance. This we regard as a schemata helping students reading nature and knowing the importance of producers in any ecosystem.

Question 5. "Look at all the animals we have caught. Please try to tell me what they are and how you think they live in this pond? What are their roles?"

Categories: Functions of the plants in the pond	Interview III
1. No reference to any function of plants in the ecosystem.	1
2. Plants are food for others.	2
3. Plants produce both food and oxygen for all the animals (not mentioning that the products are necessary for the plants themselves).	12
Total	15

Figure 13. Functions in the ecosystem. The students' level of understanding plant functions in the ecosystem. Each student can only score at one level in any interview and the total sample is 15 students

Categories: Functions of the animals in the pond	Interview III
1. No reference to any function of animals.	2
2. Students refer to herbivores (mention snails) and decomposers (mention water lice).	4
3. Students refer to functional groups as in category 2 but also add carnivores such as dragon fly larvae or water beetle expected to be carnivorous.	6
4. Students refer to functional groups as in category 3 but also mention generalists in the ecosystem referring back to generalists in the forest (e.g., ants).	3
Total	15

Figure 14. Functions in the ecosystem. The students' level of understanding of functions. Each student can only score at one level in any interview and the total sample is 15 students

This question is aiming at illustrating how the students can relate the morphology and behaviour of the animals to their ecological roles (equivalent to the topic organisms Interviews 1 and 2) (Figure 14).

Two students cannot recognise any animals "I have forgotten it and I don't like animals" (Alice). These two students were not particularly fascinated by the invertebrates from the pond and we regard their answers as an easy way of not having to engage in studying the animals. Four students refer to herbivores and decomposers. They identify snails and generalise them as herbivores, and water louse as decomposers. This correlation seems reasonable to draw since the students have seen many snails and woodlice in the forest and discussed their functions. Nine students also assume dragonfly larvae and/or water beetle to be predators. For example:

> Ooh that one must be a predator. Yes it has big eyes and mouth and it moves fast. Yes it must be … if you compare it to the slow wood lice in the water, I mean those [points at the water louse]. (Fredric)

Analysis. In the forest most students were familiar with the naming of the most abundant organisms, which is not the case in the pond. Still students often relate the animals to functional groups based on their morphology and their pattern of behaviour. This we see as an underlying understanding of the trophic levels necessarily occurring in any ecosystem as well as a generalisable understanding of the correlation between physiognomy and ecological role.

Discussion of the Findings

Decomposition, Photosynthesis, and Cycles of Matter

The teaching approach has been top down, starting with the overall processes and cycling of material in the ecosystem as has been discussed several times in the course. Decomposition seems to be a linchpin concept helping the students to recognise the cyclical processes in ecosystems. In the second interview most students had a cyclical idea where plants turn into soil by decomposers and something in the soil is cycled. This something was energy for some students, and for others it was sugar or minerals. In the transfer interview they not only mention the importance of the decomposers, but they also recognise them since they relate the decomposers found in the pond to the equivalent functional groups found in the forest. Those students show a meaningful understanding of the importance of decomposition as a condition for sustainable ecosystem functioning.

Photosynthesis is complicated on a behavioural level but on a functional level it is recognised by almost all students. Decomposition is more intuitive than photosynthesis but students express that plants are decomposed and turned to soil, energy, or minerals, and this is cycled in the ecosystem. If cycling is limited to matter, many students follow the discussion but it seems obvious that those few students who can relate the cycling of matter to both photosynthesis and decomposition, and who say that carbon is necessary for organic material, have a meaningful understanding on a behavioural level that could be referred to as a schema that is transferable between ecosystems. Shortly after the transfer interviews, the students constructed mini-ponds in the field and their discussions were recorded. An excerpt from one of the group discussions illustrates that Carol (Student E) and Hugh express a meaningful understanding of the carbon cycle when they watch their mini-pond and discuss its future:

Andrew (Student B):	Snails will probably survive the longest because they are both plant eaters and decomposers and they have like ee food all the time kind of.
Hugh (Student A):	Well I mean this system won't die at all because even if the animals die then the plants will still survive, no?
Andrew:	mmm.
Carol (student E):	Oh no!
Hugh:	Oh yes!
Carol:	Can they do that under the surface then? Because above the surface they cannot survive. They need carbon dioxide.
Hugh:	Yes but that is abundant in the water I think.
Andrew:	No not all the time.
Hugh:	No of course that is why the animals are necessary: Yes of course!!
Carol:	So, when the animals have died the plants won't live much longer.
Hugh:	No that is right.

If we compare this discussion with an excerpt of Alice's discussion about the role of the plants by the pond, it seems as if the rote learning without underlying understanding does not lead to transfer:

Alice:	I think the plants are most important here.
Interviewer:	Ok why do you say that?
Alice:	Well I don't know. Oh yes for the reason that everything has to go round.
Interviewer:	How do you mean everything?
Alice:	Yes the sun shines and ooooh it is so difficult. You know the carbon dioxide going into the plants and they give us oxygen to breathe, or … Eeeh … I can never remember this properly.

If we look at this from an epistemological perspective we believe Ausubel's model of meaningful and rote learning fits as a description of the different groups of students learning about photosynthesis and decomposition on a behavioural level (Hmelo-Silver & Green Pfeffer, 2004), where some made it meaningful, as Carol and Hugh did, and others never learned it as more than a rote equation without much meaning, as Alice indicates. When meaningful learning is accomplished, then:

> … eventually new meanings become, sequentially and hierarchically part of an organized system, related to other, similar topical organizations of ideas (knowledge) in cognitive structure. It is the eventual coalescence of many of these subsystems that constitutes or gives rise to a subject-matter discipline or a field of knowledge. Rote learning, on the other hand, obviously do not add to the substance or the fabric of knowledge inasmuch as their relation to existing knowledge in cognitive structure is arbitrary, non-substantive, verbatim, peripheral, and generally of transient duration, utility and significance. (Ausubel, 2000)

According to the schemata mentioned earlier, Carol's understanding of the behaviours of plants and decomposers in the ecosystem and their essential roles for ecosystems functioning we regard as a schema that is transferred to the new environment. Other possible schemata for reading nature are the basic functional understanding of plants as producers of food and oxygen, and are therefore expected to be found in all common ecosystems as well as the function of decomposers necessary for the recycling of matter. In this study we did not include the immensely important microbial decomposition, thereby leaving out the most important actor, but nevertheless most students expressed an understanding of the two important processes and their macroscopic actors in the ecosystems. Cycling of matter in general still seems to be problematic for most of the students when they are asked to be concrete about what is cycled and why this is important.

Systems as a Whole: Dynamics, causality, and organisms

Systems reasoning relating biotic and abiotic factors is difficult, and students often refer to biotic causal relations directly linked to the nearest level up or down in the ecosystem (e.g., how plants are affected by the number of plant eaters but not by the level of carnivores). Compared with the first interview when students almost only mentioned superficial structures in the ecosystem, such as trees or grass, they now express more functional relations and causal effects on more of a systems level. Despite the lacking knowledge of the different organisms on a species level, many students can generalise about the functional groups of the organisms they catch in the pond. The knowledge of how to tell whether an animal is a decomposer, a predator or a herbivore seems to be useful when they describe the ecosystem on an organism level and they show an ability to know what to look for. They have ideas about what functional groups of organisms they expect to find and how to relate species to functional groups, which we see as important parts of reading the new environment and can be considered transferable schemata. Regarding the dynamics and ongoing succession in nature, this is obviously difficult for students to relate to.

Not a single student expressed that the lake will change over time, which echoes what they said in Interview 1 and which supports research about students' problems of predicting slow and gradual changes in the environment (Resnick & Wilensky, 1999). A majority of the students mention that there has to be a structure in the ecosystem where the plants are dominant in biomass over the herbivores, which are dominant over the carnivores. The model of a food pyramid is expressed and they can define pond organisms fitting into every level of the pyramid including the decomposers. This food pyramid we see as a schema helping the students reading the pond on a functional level.

Methodological Issues

Our ambition is to illustrate how students can transfer their ability to read nature. This requires data on the learning outcome from a teaching sequence aiming at developing this ability. Students' ability to read the forest has therefore been the foundation for drawing conclusions about their transfer. This is the reason for collecting data on students' expressed understanding using a variety of sources such as concept maps, interviews, and recorded field activities. This is also the reason for leaving the teacher virtually anonymous in our study. What she did and said is critical for student learning but our focus is on the outcome, and we have described the theoretical content and the multiple contexts of instruction that we regard as important background information.

What is interesting to notice from a methodological perspective is that the different methods contribute with different kinds of information. As an example, we notice that when students draw concept maps describing the forest ecosystem, they include other concepts compared with what they say in the interview about the same ecosystem. It seems as if concept maps cue answering on a behavioural level on the molecular scale when describing photosynthesis, decomposition, and cycles, whereas in the interviews this is mentioned on a more functional and superficial level. Signs of ambivalence and uncertainty about scientific phenomena brought up in the interviews can often be confirmed in the group discussions where students challenge each other's ideas in a different way to that which we want to do in the interview situation. The different data contribute to a rich and complex portray of each student's understanding. Every method for collecting data on students' understanding has its limitations. Schmid and Telaro (1990) have, for example, shown that students often find it difficult to make concept maps, and that the difficulties not necessarily have to do with their understanding of the topic studied but rather that the instrument suits some students better than others. We have therefore found the combination of research methods fruitful.

Implications

An important question for curriculum developers is how best to foster the integration of knowledge that understanding ecology and reading nature requires. The results of this investigation suggest that the structural and behavioural level according to the definition of Hmelo-Silver and Green Pfeffer (2004) is difficult for the students to transfer to new environments. The structural level has to do with naming of organisms, and we concur with many others (Bebbington, 2005; Rickinson et al., 2004; Lock, 1998) in their concern about the decline of general knowledge about our common plants and animals. In an earlier study we have shown that student-teachers after a course in ecology found the recognition of species an eye opener, helping them to read nature and to see nature with new eyes (Magntorn & Helldén, 2005). Naming plants and animals has little intrinsic value, as we see it, but when naming is related to functional level—saying, for instance, that the woodlice in the forest have the same ecological function as the waterlice in the pond—then the taxonomy is important for reading nature. Structural and functional aspects have to be combined. Behavioural level relates to the question "how" and, when it comes to cycling of matter and flow of energy on behavioural level, our findings corroborate the numerous studies showing that students generally find it difficult to relate to these abstract, non-visible entities (Pfundt & Duit, 2002). Is the answer to delay the instruction of biochemistry and processes on a molecular level until upper secondary school, when even then few students achieve a clear understanding of their principles (Leach et al., 1996), and focus ecology education within the realm of nineteenth-century naturalists who lacked the knowledge of concepts such as biochemistry (Brown, 1994)? Could the naturalists read nature or are the "molecular spectacles" a prerequisite for this ability? We believe in the combination of the two. Realising the importance of plants for producing sugar and oxygen is important for reading nature, but without the behavioural aspects on molecular level the distinction between linear flow of energy through the ecosystem and the cycling of the particulate matter is very difficult to make. An alternative is to build a foundation for understanding by focusing on concepts for which students have intuitive ideas that are more compatible with expert proposition, which can anchor the learning of material that is more difficult. This requires acknowledging, that concepts such as energy and matter, serving as core understandings of modern ecologists may not be as foundational and generative for children. In our top-down approach we started with photosynthesis and respiration on a molecular level. Hogan and Fisherkeller (1996) suggest starting with the more intuitive concept of decomposition, which can provide a bridge to more abstract nutrient cycling concepts. Focusing on existing macroscopic, descriptive, and functional views of food, eating, and excretion (Barker & Carr, 1989) may provide a bridge to molecular representations of ecological processes.

We believe the functional level to be of great importance for reading different environments. Students' abilities to recognise organisms to functional groups in the ecosystems and to know what they expect to find seem to be important. The food pyramid as a model illustrating the linear energy flow from the bottom to the top of the ecosystem together with the general morphology of organisms in relation to their function seem to be transferable linchpin concepts for reading the new environment. We regard them as schemata for many of the students. In order for transfer to be possible, the person has to have similar earlier experiences (Bransford et al., 1999). So, if a goal with the ecology education is that students can read different environments, we believe it is important to first of all go out in nature, and while there focus on the organisms and use them and their ecology as a point of departure for discussing the function and behaviour of the ecosystem studied. Students have to be introduced to observing the structures—both biotic and abiotic—and to be familiar with models such as food pyramids and metaphors that can be related to these structures. One example of how students can transfer their functional level of understanding between ecosystems is when Hugh, looking at the organisms from the pond, says: "I cannot see the decomposers here now but I know that they have to be here, so I will soon find them".

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Appendix. Total score for all 15 students (Students A–O), in all three interviews

	Students from A to O. Students are ranked highest (A) to lowest (O) based on the results of the score in interview 1. (X= max score for each question).																
Interview 1+2	X= max	int. 1 **A**	int. 2	Int. 1 **B**	Int 2	int. 1 **C**	int 2	Int 1 **D**	int 2	Int 1 **E**	int. 2	Int 1 **F**	int 2	Int 1 **G**	int 2	Int 1 **H**	int 2
Quest. 1	**4**	3	4	4	4	3	4	2	4	2	4	2	4	2	4	2	3
Quest. 2	**4**	3	4	2	4	3	3	3	4	3	4	3	4	3	3	3	4
Quest. 3	**3**	3	3	2	2	2	2	2	3	1	3	2	2	1	3	1	1
Quest. 4	**4**	3	4	2	2	2	2	2	3	2	3	2	2	1	3	1	3
Quest. 5	**4**	1	4	1	4	1	3	1	3	1	4	1	1	1	2	1	3
Max score 19	**19**	**13**	**19**	**11**	**16**	**11**	**14**	**10**	**17**	**9**	**18**	**10**	**13**	**8**	**15**	**8**	**14**
Transfer interview																	
Quest.1	**3**	3		3		3		2		3		1		1		2	
Quest.2	**3**	1		1		1		1		1		1		1		1	
Quest.3	**3**	3		3		2		2		2		1		1		2	
Quest.4	**3**	3		3		3		3		3		3		2		3	
Quest.5	**3**	3		3		3		3		3		2		3		3	
Max 15	**15**	**13**		**13**		**12**		**11**		**11**		**8**		**8**		**11**	

Appendix. ***(continued)***

		Students from A to O. Students are ranked highest (A) to lowest (O) based on the results of the score in interview 1.													
Interview 1+2	X = max	int. 1 **I**	int. 2	Int. 1 **J**	Int 2	Int. 1 **K**	Int 2	Int 1 **L**	int 2	Int 1 **M**	int. 2	Int 1 **N**	int 2	Int 1 **O**	int 2
Quest. 1	**4**	1	2	2	3	2	2	2	3	2	2	1	2	1	2
Quest. 2	**4**	3	3	2	3	1	2	2	4	3	4	3	3	1	3
Quest. 3	**3**	2	3	1	1	2	2	1	3	1	2	1	1	1	1
Quest. 4	**4**	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Quest. 5	**4**	1	3	1	2	1	2	1	4	1	2	1	1	1	1
Max score 19	**19**	**8**	**13**	**7**	**11**	**7**	**10**	**7**	**16**	**8**	**12**	**7**	**9**	**5**	**9**
Transfer interview															
Quest.1	**3**	3		1		3		3		2		1		1	
Quest.2	**3**	1		1		1		1		1		1		1	
Quest.3	**3**	2		1		1		2		3		2		1	
Quest.4	**3**	3		3		3		3		3		1		2	
Quest.5	**3**	3		1		2		3		2		2		1	
Max 15	**15**	**12**		**7**		**10**		**12**		**11**		**7**		**6**	

Paper III

Educational Research

Reading nature from a 'bottom-up' perspective

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This paper reports on a study of ecology teaching and learning in a Swedish primary school class (age 10-11yrs). A teaching sequence was designed to help students read nature in a river ecosystem. The teaching sequence had a 'bottom up' approach, taking as its starting point a common key organism - the freshwater shrimp. From this species and its ecology, the perspective was broadened to involve studies of the interrelations between organisms and finally to the relationship between biotic and abiotic factors. A large part of the instruction took place outdoors. Students were interviewed three times during the course when they were presented with a tray full of objects (both biotic and abiotic) from the ecosystem. The students' task was to name and describe the objects and then to link them up in as many relevant ways as possible, explaining the reasons for the links. The interviews have been transcribed onto concept maps and SOLO-taxonomy was used to illustrate their developing ecological understanding. Results indicate how students related several abstract processes and correlations back to the key organism studied early in the teaching sequence.
Key words: Ecological literacy; SOLO-taxonomy; Concept maps; Field studies.

Introduction

"I know him. He is the freshwater shrimp. He is very important for the river … he is the cleaner. You know he loves all the dead leaves and so he keeps the river tidy." (Peter, 10 yrs, in interview 2). This quote is from one of the young students who followed a teaching sequence aimed at *reading nature* in a river ecosystem. The teaching sequence had a 'bottom-up' approach (Magro *et al*, 2001) in the sense that it started with the direct contact with an individual species, which was studied in detail. This was followed by studies of its relationships to other organisms and finally to the whole community, and how these were affected by and involved the flow of energy and the cycling of matter in the river.

The *ability to read nature* is central in this work and needs a brief explanation. We see it as an important aspect of ecological literacy which is ideally about developing a rich knowledge base and multifaceted beliefs and/or philosophies about the environment which lead to ecological sustainability (Orr, 1992). *Reading nature* focuses on ecology and the context is outdoors. It has to do with an ability to recognise organisms and relate them to material cycling and energy flows in the specific habitat which is to be read. It has to do with the natural world that we face outside; the tools we have are our experiences from previous learning situations both indoors and out-of-doors. In this context it has to do with students' ability to give a relevant interpretation of the river as an ecosystem, based on recognition of common organisms and awareness of their autecology. It also has to do with understanding the relationships between functional groups and how abiotic factors, such as light and the speed of water, influence the whole ecosystem. For further description of the concept see Magntorn and Helldén (2005).

Research on students' learning and understanding of ecology suggests that developing an understanding of ecosystems and their functioning is difficult. Leach and colleagues did a cross-sectional study of 5-16 year old students and their understanding of ecology. They found that students do not see the ecosystem as an interrelated whole, i.e. photosynthesis, respiration and decay are not viewed as cycling of matter in ecosystems (Leach *et al*,1996). A review of the literature suggests that students do not have a good grasp of the complexity in food webs, of energy flow or of the dynamics and structure of ecosystems (e.g. Adeniyi, 1985; Gallegos et al, 1994; Hogan and Fisherkeller, 1996; Grotzer and Bell Basca, 2003; Carlsson 2002).

This research refers to the upper level of *reading nature*, with abstract processes and relations. In this study we are also interested students' knowledge of the individual organisms, representing the bottom level in this study. This is often not part of students' common knowledge. This was illustrated when a large sample of 12-14 year olds were asked what sort of living things they would expect to find in freshwater. Frogs, tadpoles and fish were commonly mentioned but few made reference to plants or invertebrates (Lock *et al*, 1995). Other studies have shown that students have great difficulty in the classification of invertebrates (e.g. Kattman, 2001). Since many of the invertebrates found in a river are insect larvae changing into flying adults, it is also important to know the difficulties young students have with life cycles since they tend to forget the egg stage and the cycling of life stages (Shepardson, 2002). From this review it appears that *reading nature,* with its linking of organisms' ecology to systemic thinking, is a challenging goal to strive for. Its relevance is supported by Slingsby and Barker (1998) when they recommend a 'bottom up' approach, starting with whole organism ecology, in their model of an improved curriculum in ecology education.

Objective

The main objective is to characterise students' sophistication and ability to read nature as they progress through a teaching sequence designed to develop an understanding of ecosystems via an initial focus on one species.

The teaching sequence and data collection

The teaching was carried out in a Grade 3-4 class (yrs 10-11) with 23 students. The school is a public school in a small community in southern Sweden. Instruction was carried out by a teacher from the local nature school together with the ordinary class teacher. There was continuous negotiation between the researchers and the teachers about the content and design of the teaching sequence. The overall sequence comprised four phases spanning seven lessons of varied duration from 80 to 200 minutes (see Figure 1).

Space constraints make it necessary to present a short synopsis of the sequence but the authors have made a video highlighting the teaching design and student activities which is available on *mms://194.47.25.160/mna/vramsafilmen.wmv*. Basically each lesson started with a classroom discussion framing the task to be studied. This was followed by fieldwork along the nearby river and collected material was often brought back to the classroom for further study. The students often worked in small groups and their observations and findings were discussed and summarised in the whole class.

Phase 1 – Autecology (i.e. the ecological relationships of a particular plant or animal species) of the freshwater shrimp (*Gammarus pulex*). Collection of the animal in the river was followed by 'brainstorming' when students came up with questions about the shrimp that they could answer by observation or experimentation. Relevant questions and the conclusions from all the observations were discussed.

Phase 2 – Taxonomy (i.e. identification and grouping of animals) *and autecology*. The children collected different organisms in fast and in slow sections of the stream and studied their adaptation to the environment. Herbivores and predators were determined according to their morphology and behaviour i.e. those with large eyes, large mouth parts and rapid movement are often predators. Life cycles were discussed and sealed aquatic ecosystems were constructed and discussed according to the 'roles' of plants, animals and abiotic factors such as light and air.

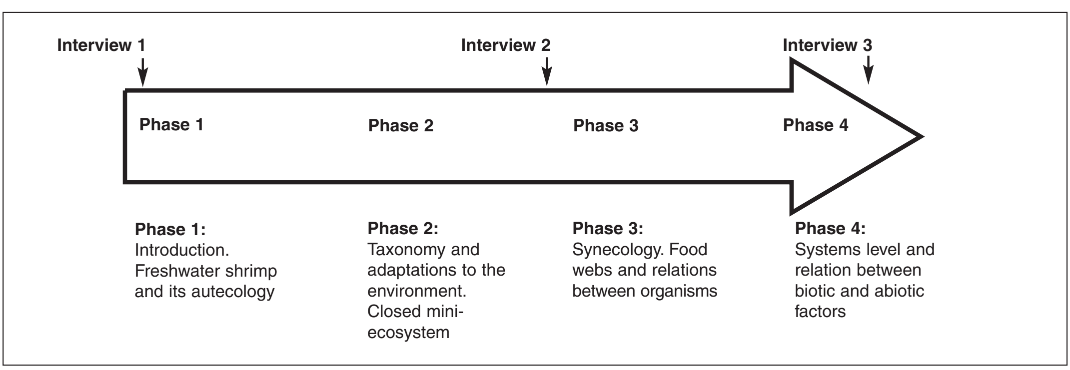
Phase 3 – Synecology (i.e. the ecological relationships of a community). This involved the introduction of food webs and food pyramids based on the organisms observed in the river. A litterbag experiment was conducted where the children put freshwater shrimps and/or the water louse (*Asellus aquaticus*.) in small net-bags together with green and brown leaves. The bag was then put into the river. After a week it was collected and studied resulting in the discovery that the animals preferred brown leaves and could be considered decomposers in the ecosystem.

Phase 4 – Systemic view (i.e. the relation between biotic and abiotic components and the flow of energy and cycling of matter in the ecosystem). A systemic view of the ecosystem was discussed and students were introduced to photosynthesis and energy flow in the ecosystem by discussing plants' ecosystem functions and by building a model of a food pyramid. The sealed ecosystem was opened and examined. The relations between abiotic and biotic factors were discussed and investigated focusing on the importance of water speed, the surrounding environment and the human impact on the river ecosystem.

Research design

We collected data from three interviews with each student (see Figure 2). We decided to present the interviews as concept maps. The authors have along with many others (e.g. Kinchin, 2000) recognised concept maps as a powerful metacognitive tool for helping students understand complex notions such as ecosystems. But we applied it in its original use by Novak (1998) where he used concept maps to represent large amounts of interview data. A concept map is normally represented in a hierarchical fashion with the most inclusive and most general concepts at the top. White and Gunstone (1992) defined good maps as those that displayed considerable

Figure 1. The teaching sequence together with the three tray interviews. Interview 1 was conducted in February before the teaching sequence and interview 3 in May, after the teaching sequence.



amounts of detail, a variety of types of relations and rich patterns of cross-relations.

We designed an interview method, the tray interview, inspired by ideas from Mellgren (2004). The student was presented with a large tray filled with objects from the river together with pictures of the river and its surroundings. The main interview question was: "Tell me what you think the objects on the tray are and explain how you can link the objects on the tray together in as many ways as possible to explain life in the river?" This resembles the construction of an 'oral' concept map without the paper and pencil work.

The interviews were video-recorded and they were jointly transcribed, rather than interpreted, by the researchers into a concept map. This means that the hierarchy in the map is student-based and reflects the order in which the student chose to mention the objects in the interview. What the student saw as most important is not always what a scientist would suggest. In relation to the bottom-up teaching approach, this means that normally subordinate concepts, such as names of organisms, are presented super-ordinate to more general concepts such as photosynthesis. This is of course mirroring the line of instruction but it also says something about young students' fascination for live animals.

The objects on the tray included a large number of different living invertebrates, representing herbivores, decomposers and carnivores, and both the adult and larval stages of dragonflies. There were also live aquatic plants and brown half-eaten leaves together with pictures of a salmon and of a human. Non-living components were represented such as gravel and rocks from the river bottom together with a glass of water, a dish with air (representing air or gases). Pictures of the sun and of the river in winter and in summer were also presented to the students. We found that students were encouraged and challenged by the task and the large majority tried hard to link the parts to a whole.

The SOLO analytical framework

In order to structure our analysis of the tray interviews we have used the SOLO taxonomy (Dart and Boulton-Lewis, 1998; Biggs and Collis, 1982). It offers a model for characterising the levels of sophistication of children's developing explanations. The SOLO taxonomy focuses on sophistication and does not necessarily equate with conventional scientific ideas. The five levels of the taxonomy are described below in the context of ecology.

1. *Prestructural.* The responses are often inadequate and the student is frequently referring to irrelevant aspects.

2. *Unistructural.* Single aspects of the task are picked up, but the task itself is not attacked in an appropriate way. The student reasons in the relevant mode but only in single step relations without any mediating description of a sequence of causally linked events or relations. This level of explanation indicates fragmentary understanding without any attempt to make either synthesis or systemic analysis of the ecosystem.

3. *Multistructural.* Causal chains are given in the explanations, linking two or more objects together and referring to relevant ecological theory. There is no attempt, however, to raise the explanations and linking to the level of a generalisation. No process or abstract relations are discussed.

4. *Relational.* Relational explanations extend relevant points to a general principle, or interrelationship between factors.

5. *Extended abstract.* The coherent whole can be generalised on a concrete as well as an abstract level to other ecosystems.

The ability to *read nature* is related to age and experience and, of course, a biologist reads nature differently from a primary

Table 1. The SOLO-levels in relation to the ecological content knowledge. The SOLO-levels are presented vertically on the left and levels are related to the sophistication and correctness of the ecological categories presented horizontally in the chart.

SOLO	Autecology + Life cycles	Synecology	Systemic view
Prestructural	Trivial single aspect aut-ecological links such as "fish need water". Life cycles are not discussed in a relevant way.	No relevant statements regarding how the organisms coexist in the ecosystem.	No relevant statements regarding how the biotic and abiotic components make a system with flow of energy and cycling of matter. Parts and whole are not related.
Unistructural	As above but also relevant single aspect links to organisms' morphology or behaviour.	As above but also single step links between different organisms such as who eats whom.	As above but also trivial links between biotic and abiotic components such as all animals need air and light.
Multistructural	Two or more morphological or ecological aspects are linked to separate organisms, often related to their habitat. Life cycle of one or a few organisms is often described.	As above but also linking more than two organisms to a food chain. Recognition of functional groups and their common features.	As above but also trivial multi-step links between biotic and abiotic components such as plants need gravel and light to grow and shrimps must eat them, otherwise there are too many
Relational	As above but several aspects are integrated in a structured and meaningful way describing the relation between single organisms and habitat.	As above but the community of organisms are often linked as in a food pyramid. The importance of plants for the whole ecosystem is recognised. Different life cycles are compared.	Energy flow in ecosystems is described, linking the sun with plants and consumers. The shrimp is related to water quality. Cycling of matter is not discussed.
Extended abstract	As above but the student can generalise the link between taxonomy and autecology between ecosystems.	As above. Populations are correlated to each other and to the function of the ecosystem. Life cycles are related to variation in biodiversity in the river over the year.	As above but there is some generalisation between the river and the sealed ecosystem or other ecosystems. General conclusions about energy and cycling of matter are drawn.

school student. The principles on which the interview data were assigned to the five SOLO-levels mainly hinged around the sophistication of causal notions within – as well as between – the categories of autecology, synecology and systemic thinking (see Table 1). The table is the result of analysing tray interview data over and over again, searching for patterns of significant developmental steps towards relevant complex thinking of the river as an ecosystem. The table should be read horizontally: for example, a student on a relational level of reading the river has reached this level on all three categories. These SOLO-levels are based on our interpretation of the total interview material.

Results

Figure 2 illustrates students' developing ability to read nature. The development itself is no surprise, especially not since the SOLO-categories are based on the interview material. What is of greater interest, though, is the qualitatively different ways they read nature in the later interviews. Initially all students had a limited ability to link the objects on the tray. They did not know the names of most organisms and they knew very little about their autecology. In the second interview all students related objects to the autecology of the freshwater shrimp and how this in turn related to a few other organisms in the river. Life cycles, adaptations to waterflow and trophic relations were discussed on a multi-structural level by the majority. Two students related the autecology to processes in the river such as the importance of plants for all life in the river.

In the third interview, as in the previous, most students started by describing the freshwater shrimp and its autecology. They often added synecological and systemic relations linking it to water quality, trophic relations and energy in the ecosystem. Fifteen students read the river on at least a relational level, where they linked the organisms to the function of the ecosystem. To illustrate the developing ability to read nature we selected two students, Anna and Peter, whose interviews will be presented as concept maps together with short excerpts of their comments. In general, their developing ability to read nature corresponds with the majority of the students but they were also chosen since they appreciated different parts of the teaching content.

The developing ability to read nature of Anna and Peter

The teacher, with 30 years of teaching experience, described her class as "a positive class but there are no really strong students and as a whole I believe the class is about average".

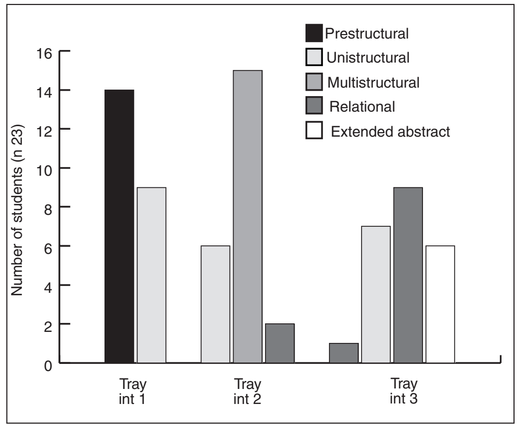


Figure 2. The number of students reaching the different SOLO-levels in tray interviews 1, 2 and 3.

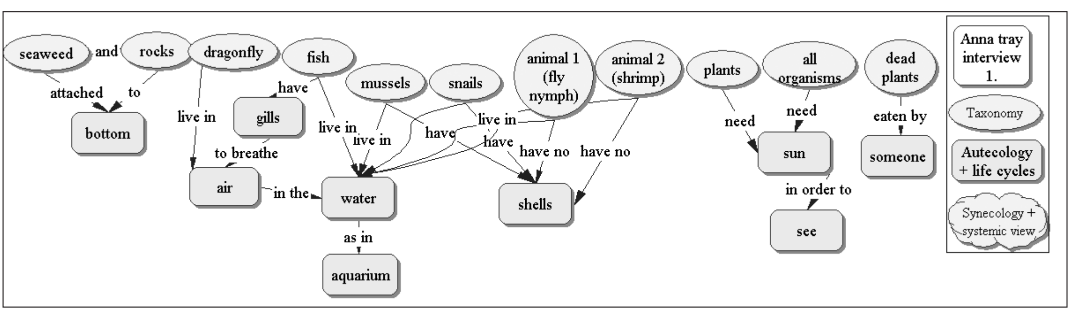
Prior to instruction she described Anna as "quite lazy but good at logical thinking" and Peter as "interested in most things and good at observation". Peter said he had been fishing in the river a few times, but apart from that both students said they had no prior experience of studying life in a river.

Initially they showed a very limited ability to read nature, citing mainly single step and often trivial relations between the objects. There were generally no cross-links and they always started with the organisms. As indicated in the concept map (Figure 3) Anna's species knowledge was restricted to fish, dragonflies, mussels, snails and seaweed. The structure of the concept map reveals a limited ecological understanding involving only a few species.

Teleological reasoning was common, such as regarding the sun as important for visibility or the water as important for animals to swim in. Reasoning about the functions of the organisms in relation to whole ecosystem was largely absent. This was not surprising and is supported by other studies of novices describing ecosystems: Hmelo-Silver and Green-Pfeffer (2004) showed that 13-14 year old students, when asked to describe and explain an aquarium, mainly described structures such as fish or water without mentioning the functions of the biotic and abiotic components and how they interacted.

In the first interview it was already apparent that Anna and Peter had slightly differing foci when reading nature. Anna was more interested in finding generalisations from single observations. One example of this was when she said that fish had gills for breathing and that they breathed air in the

Figure 3. Anna's tray interview 1. The concept map contains concepts marked with different symbols for indicating the taxonomic level (ellipse) and autecological level (rectangle). The concept map is the researchers' interpretation of her interview.



water as they do in an aquarium. Peter on the other hand was more interested in the details and he did not generalise his observations to other relevant situations as much as Anna did. He often presented narratives and one example was his observation of the dragonflies when he was fishing. He said:

> *I have seen them when they land on the water and they take up something, maybe water. They take it until they turn red and then they fly away again. Yes I have seen that*" (Peter interview 1).

This statement, despite its factual error, illustrates Peter's curiosity about the animals and their behaviour. We classified Anna's ability to read nature as prestructural and Peter's as unistructural. The difference between them was that Peter linked several different organisms e.g. saying that the salmon can eat different animals, pointing at the shrimp and the water louse.

In the second tray interview, both students started by describing the shrimp and its autecology. Anna's links were mainly of an ecological character such as how it breathed and where in the river she found it. She also added its role as a cleaner, eating dead plants. Peter on the other hand mainly linked morphological rather than ecological characteristics to it. They both discussed life cycles and Peter described life cycles of both dragonflies and stoneflies. He was fascinated by the resemblance between their larval and adult stages. Anna compared the shrimp and the dragonfly saying that they either have full metamorphosis as the dragonfly or no 'real' metamorphosis as the shrimp.

Peter found it challenging to name all the organisms and he identified more organisms but made fewer autecological links to them than Anna did. They both linked the morphology of herbivores and carnivores to typical animals they had found in the river. Peter's strong interest in morphological details is exemplified by a typical statement when he was looking at a caddis larvae with a flat case made of small stones.

> *Peter: Yes this is with a house made of stones – I know it must live in the fast stream. So, you have been out in the fast stream catching it, haven't you?*
>
> *Interviewer: OK. How do you know?*
>
> *Peter: Yes, well otherwise it would just be washed away.*

An example of Anna's stronger interest in systemic relations rather than in the different life forms could be seen when she tried to link the plants and the decomposers present in the excerpt below.

> Anna: *Well the shrimps and the water lice eat the dead leaves and that is food, kind of, and then it comes out as faeces.*
>
> Interviewer*: OK. Anything else?*
>
> Anna: *Yes, it is washed out in the river and maybe the plants will have it again as fertilisers or something, I'm not sure.*

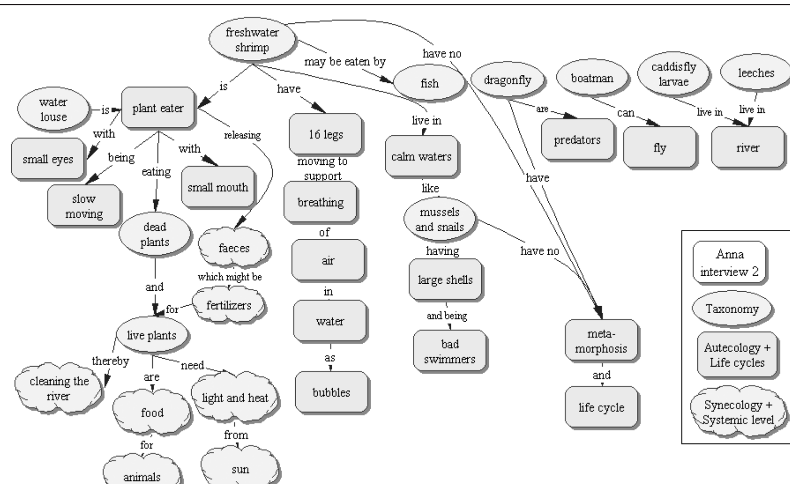
Synecological links were still very infrequent and were often trivial and incorrect. For example, the relation between the plants and solar energy (and its importance for the ecosystem) was mentioned by very few students, including Anna, but the process of photosynthesis was unfamiliar to them all. Both Anna's and Peter's ability to read nature in the second interview were classified as multistructural.

In the third tray interview most students, including Peter, start with the shrimp and its autecology. This is interesting since the teaching focus is no longer on the shrimp but on synecological processes including the shrimp. The links are now more of ecological rather than morphological in character as exemplified by the excerpt below.

> Peter: *It eats old leaves and therefore it kind of cleans the river and that's good for all the others.*
>
> *Interviewer: Aha?*
>
> *Peter: I know that because we made an experiment and we put them and the water louse in a bag and they got a green and a brown leaf. Then we walked down to the river and put them in the water. We walked down again after a week and then we saw that they had only eaten the brown, rotten leaves.*

Peter's experience of the episode with the shrimps is mirrored by Anna's. In her concept map she considers the feeding preferences of the shrimp. Both relate the shrimp to water

Figure 4. Anna's tray interview 2. The concepts are indicated with different symbols representing taxonomic level (ellipse), autecological level (rectangle) and (cloud) systemic and synecological level. The freshwater shrimp was her starting point and she related it to several autecological features.



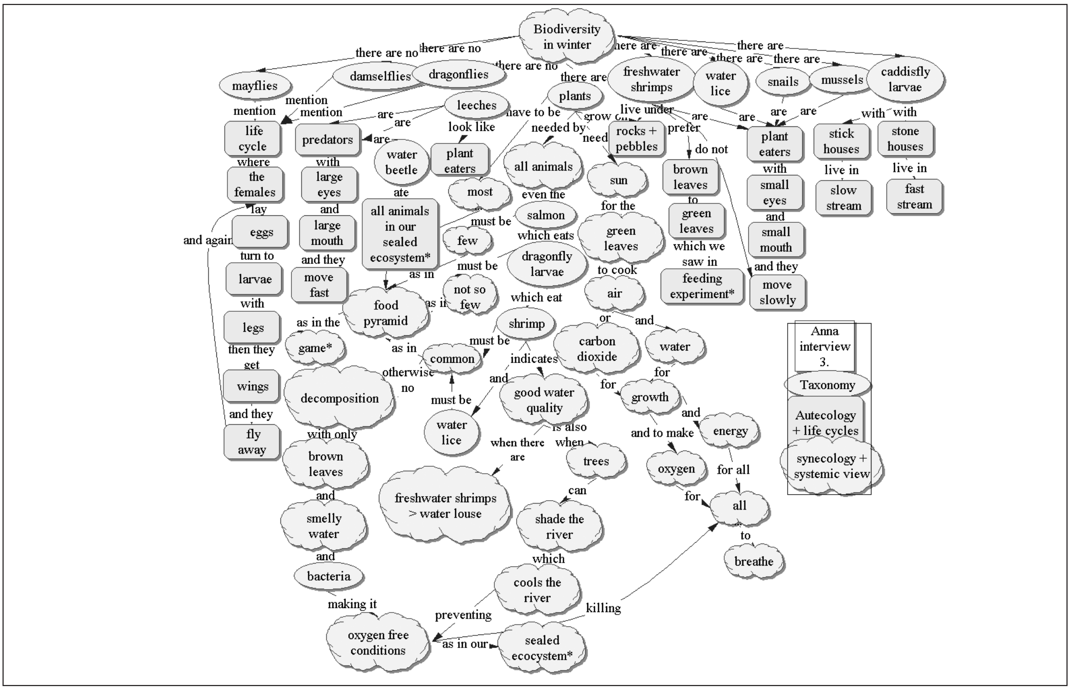


Figure 5. Anna's tray interview 3. Concepts are marked with different symbols representing taxonomic level (ellipse), autecological level (rectangle) and systemic and synecological level (cloud). * refer to items in the formal instruction.

quality, saying that finding more shrimps than water lice means the water quality is good. Peter recognises all the invertebrates in the tray and says he has made drawings of most of them in his schoolbook. Anna recognises fewer of the invertebrates but on the other hand she expresses more ecological links to each one of them. An example of the different focus can be illustrated by the following links to the same animal. Peter says:

Peter: *That one is a leech. I know there are two species of them and they move from one stone to another like this* (shows their locomotion with his fingers).

Anna: *Leeches are also predators but they don't look like it. They suck blood.*

Peter is an observer and notices animal behaviour whereas Anna is more interested in their function. Both of them discuss adaptations to the environment. Along with a majority of students they also mention the sun and its importance for the plants and subsequently for the whole ecosystem. Peter is more restricted to the model presented by the teacher where plants, shrimps, dragonfly larvae, salmon and humans are parts of the food pyramid, saying that there need to be mostly plants for the energy to support the top predators. Anna generalises from this model and adds new organisms to it without losing the main idea. The excerpt below illustrates Anna's synecological views about the importance of plants for all other organisms.

Anna: *"it will be oxygen, some oxygen which everyone can breathe. And they need those stones since they grow on them and dragonfly larvae need animals, oxygen and light so they see and then the shrimps and all other plant eaters need leaves to eat which, er, need the sun and all that I said before. So it's kind of connected. Everyone needs air from the plants yes everyone is connected with the plants even the salmon which eats such, er, dragonflies so everything has to be there.*

This excerpt illustrates a systemic level of reasoning which both students have, but Anna is more elaborate. In the short excerpt below Anna refers to the principle of too many predators resulting in too few shrimps and water lice in the river. She exemplified systemic reasoning with her recollection of an experiment with the sealed ecosystem where it turned anoxic and very smelly after a few weeks.

Anna: *Yes there has to be mostly leaves. Yes, since they have to eat all the leaves and there are so many mayfly larvae and shrimps. Yes, otherwise there is not enough food for the salmon who have to eat many dragonfly larvae every day... We played the game which showed that.*

Interviewer: *OK, but how can it be too many of these (points at dragonfly larvae).*

Anna: *Yes, then the shrimps and water lice would have been extinct and then it would only have been a lot of dead leaves and bacteria and no air in the water. The river would probably have smelled bad just like our "river in a jar" [sealed ecosystem] did. There all animals died and there were lots of bacteria breathing all the oxygen. They eat a lot and they breathe a lot so they finish the oxygen.*

Both Peter and Anna often referred to episodes from the outdoor activities or hands-on experiments and classroom observations when they discussed complex relations on synecological or systemic level. It is interesting to see how they developed their ability to read nature over the course. Peter's strong interest in taxonomy and autecology was his focus and when he read nature it was a rich story about the life and life

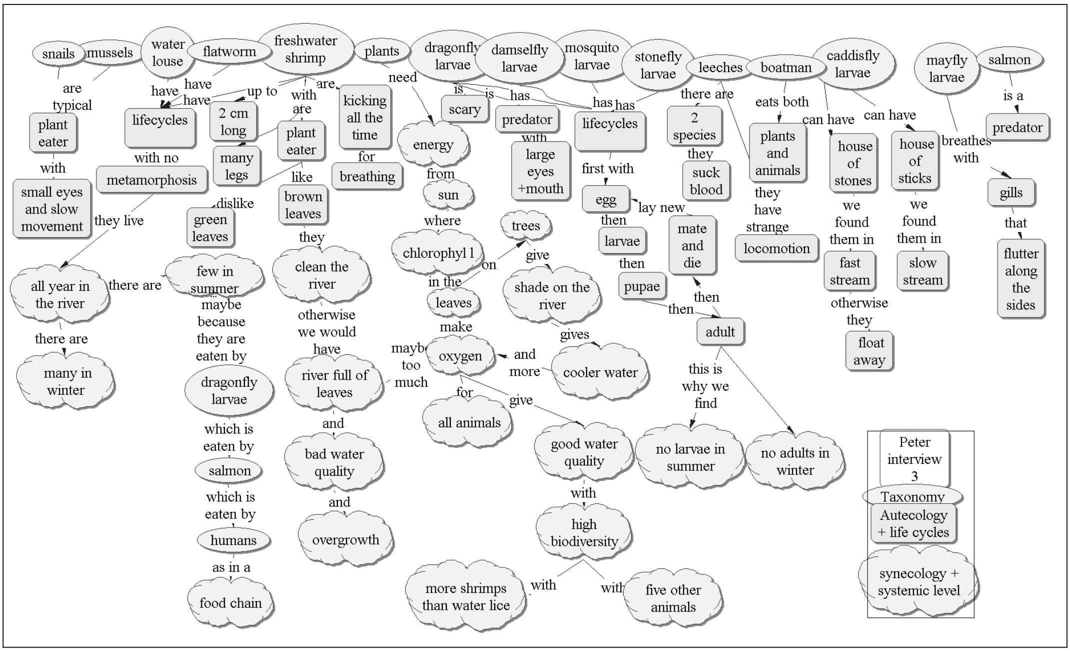


Figure 6. Peter's tray interview 3. Concepts are marked with different symbols representing taxonomic level (ellipse), autecological level (rectangle) and the systemic and synecological level (cloud).

forms in the river. This is mirrored in his concept map from interview 3 (Figure 6). The upper part with taxonomy and autecology is very dense but the links to the systemic levels are not so rich. Anna on the other hand had never been very interested in the animals but she used her knowledge of taxonomy and autecology to link the animals to a more systemic reading of nature than Peter did.

In her concept map from the third interview she had more synecological/systemic sections (i.e. links and concepts together) and she read nature on an extended abstract level where she generalised her ecological ideas from experiments and specific experiences during the teaching sequence. She says she is thinking about questions such as "how can they survive here and what are their roles in the ecosystem functioning?" Peter has also greatly developed his ecological thinking over the course but he is more restricted to the links he has heard about and his focus is on the upper parts of the concept map where the species knowledge and autecology is in focus. He reads nature on a relational level.

Discussion and implications for teaching

Underlying the whole design of this study is curiosity about how students relate the individual species to the whole ecosystem. Prior to instruction, all students had very little knowledge of the organisms in the river. This lack of taxonomic knowledge is supported by earlier research (e.g. Lock *et al*, 1995) and since *reading nature* has to do with linking taxonomy to ecosystem processes they were often struggling to find something to say in the first interview. The importance of taxonomy was mentioned by the Swedish eighteenth-century scientist Linnaeus. He wrote "*Nomina nescis perit et cognita rerum*" (If we don´t know the names the knowledge of the things themselves is worthless)(Linnéus, 1737). His point was that of communication and how crucial it is to have common names for organisms in order to avoid confusion and to be able to discuss natural history.

We started with an in depth study of the shrimp in order for the students to find out as much as possible about its morphology, behaviour and autecology. This type of inquiry-based study of a single organism, has in other studies been shown to be highly motivating for the students (e.g. Tomkins and Tunnicliffe, 2001). It was followed by identification of other organisms and their adaptation to life in the river. In interview 2, every student had something to say about the shrimp and most students could mention at least five different invertebrates and link them to their autecology. Taxonomy and autecology was linked by statements like "x lives in fast streams and has a flat body" or to the life cycles of different organisms; this resulted in single step chain structures in the concept maps indicating limited integrated knowledge. If we look at the Swedish curriculum, though, this is what ecology education should strive for. It says that students should after their fifth school year "recognise and be able to name common plants, animals and other organisms in the local environment, as well as be familiar with their environmental requirements" (National Agency for Education, 2007).

We could justifiably say that instruction has met the curricular demands, but what use is this for an ecological understanding? They are still far from readers of nature. From our point of view this knowledge is a good starting point for learning synecology where they have to see the shrimp as part of a larger system. The last interview showed that eight students did not reach a relational level which is required for synecological reasoning. These students referred to the shrimp and some of its autecology but they did not link it to relevant synecology. The move from the concrete to the more abstract is of course difficult to do but it could also be related to the interview format which does not require that they explicitly discuss the synecology. The others related the shrimps, the plants and some other organisms in synecological discussions such as exemplified by Anna and Peter. It is also worth mentioning how the design of instruction has allowed both Peter's interest for naming and Anna's interest for processes to develop.

One of the main conclusions from our study is the importance of autecological knowledge. We see it as the glue between taxonomy and systems ecology. Knowing the names and the often fascinating autecology can build an interest for learning more about the mechanisms supporting the life in the ecosystem and the relations between populations. The affective component is important and, as an example, Magro *et al* (2001) have shown that teaching ecology from a top-down approach starting with the ecosystem and not relating to the individual species has led to students losing interest and regarding the "teaching of ecology as cut off from real life and of poor appeal to pupils".

Final remark

In a review of concept development and progression within ecology teaching, Barker and Slingsby (1998) claim that a serious barrier to the teaching of ecology is the over-emphasis on sophisticated concepts, combined with a failure to allow a knowledge of whole-organisms biology to progress. They recommend a 'bottom-up' approach. We agree and in the design of our teaching sequence we have tried to meet some of their demands. What we want to stress is the idea underlying the whole idea of teaching for *reading nature:* that is the importance of fieldwork. Dillon *et al* (2006) write about the growing concern for the decreasing opportunities for fieldwork in schools and they claim that evidence from research from all around the world shows that fieldwork can have a range of beneficial impacts on participants. However, it needs to be carefully planned, thoughtfully implemented and followed up back at school. The curriculum in Sweden does not stress the importance of fieldwork, but adding the ideas of *reading nature* to the curriculum is a way of meeting the demands not only from science education research but also, at least in Sweden, of the many voices in the public debate expressing anxiety and strong concern about lack of fieldwork and growing ecological illiteracy.

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Paper IV

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Reading Nature- experienced teachers' reflections on a teaching sequence in ecology: implications for future teacher training

Abstract

This article explores experienced primary teachers views on teaching for 'reading nature'. The concept 'reading nature' has to do with an ability to recognise organisms and relate them to material cycling and energy flow in the specific habitat which is to be read. It has to do with the natural world that we face outside and the tools we have are our experiences from previous learning situations both in and out-of-doors. The teachers were asked to comment on the content of a CD-ROM with teaching sequences from a primary class studying a river ecosystem. Perceptions that teachers held were found to be supportive but complex and varied regarding the possibilities and advantages of implementing this type of teaching design in the everyday classroom. The paper finishes by identifying some implications for teacher training to support fieldwork and ecological literacy in primary schools in the future.

Introduction

In recent years, there has been a growing concern about the substantial decrease in opportunities for outdoor learning in schools (e.g. Dillon et al., 2006; Rickinson et al., 2004; Slingsby & Tilling, 2002) and the limited knowledge students have of our common animals and plants in the nearest environment (e.g. Bebbington, 2005). In the national curriculum for compulsory school in all Nordic countries there are explicit paragraphs saying that primary school students (up to year 5) should be taught about common animals and plants and about their environmental demands. It is also stressed that students should be taught about different ecosystems. However, in these curricula there are no explicit guidelines for how this instruction is supposed to be carried out and naturally there is a great variation in how teachers meet these demands.

In a previous study of 'reading nature' we designed and evaluated a teaching sequence following a class of primary school students and their developing ability to read nature (Magntorn & Helldén, 2005). The present paper is a follow up study where we discussed, with experienced practitioners, the teaching sequence in relation to its possibilities and limitations for implementation in everyday school activities. We also discussed their views of the concept 'reading nature' in relation to the national curriculum in biology education. The aim was to elicit critical aspects supporting or hindering the implementation of such a teaching design in the everyday classroom. We believe it is valuable to bring the science education research tradition closer to the world of school, where teachers with a didactical interest and with a long teaching experience can contribute with important aspects, helping to bridge the gap between research results and implementation to classroom practice. Our aims are supported by a large review on research on outdoor learning (Rickinson et al., 2004) where the authors are demanding more research in what they call "blank spots of research" One of these blank spots is "teachers and outdoor educators' conceptions of "the outdoor classroom" and the curricular aims and pedagogical strategies that they see as important for effective teaching therein"(p 56).

Leach and Scott (2002) claimed that most studies so far have focused on students' learning but there has been little focus on the importance of the teachers' role in science education and the teachers' view of learning. There are relatively few metacognitive studies on teachers view on the design of instruction. In order to implement a successful teaching design in the everyday classroom we believe it is of great importance to hear the voices of teachers with long experience. Regarding studies on teaching design there are, however, critical voices heard about the validity of such studies and several researchers have described the development of teaching sequences not as educational research but rather as developmental studies (Lijnse, 2000; Anderson & Hogan, 1999). But this is changing and today there is a growing support for seeing the evaluated teaching sequence as a research result (e.g. Meheut & Psillos, 2004). This research tradition is relatively young but the trade of designing teaching sequences is of course long and what teachers have always done. Despite this experience the tradition of publishing and disseminating it in a fruitful way is unfortunately not so well developed. Lijnse (2000) writes "The primary aim of science education research is content-specific didactical knowledge, based on developing and justifying exemplary science teaching practices". We believe our research can contribute to this aim.

Reading nature

The ability to 'read nature' is central in this work. It is described by Magntorn and Helldén (2005), but needs a brief explanation here as well. We see it as an important aspect of ecological literacy which is ideally about developing a rich knowledge base and multifaceted beliefs and/or philosophies about the environment which lead to ecological sustainability (Orr, 1992). Our phrase 'reading nature' focuses on ecology and the outdoor context. It has to do with an ability to recognise organisms and relate them to material cycling and energy flow in the specific habitat which is to be read. It has to do with the natural world that we face outside and the tools we have are our experiences from previous learning situations both in and out-of-doors. In this context it has to do with students' ability to give a relevant interpretation of the river as an ecosystem based on recognition of common organisms and awareness of their autecology together with an understanding of the relationships between functional groups and how abiotic factors, such as light and speed of water, influence the whole ecosystem.

Methods

The teaching was carried out in a grade 3-4 class (yrs 10-11) with 23 students. The school is a state school (non-fee paying) in a middle class community in southern Sweden. It is important to say that the instruction was conducted by a teacher from the local nature school (i.e. a field study centre with experienced outdoor educators, who, free of charge, visit classes in the municipality) together with the ordinary class teacher. The overall teaching sequence comprised 4 phases spanning 7 lessons of varied duration from 80 to 200 minutes (see figure 1).

All the teaching activities were video recorded. Although it was necessary to limit the total duration of the video clips to 40 minutes, so as to ensure reasonable total viewing time, strenuous efforts were made to maintain the flow and the general essence of the lessons. Field work and classroom activities with collaboration and task solving activities which dominated the instruction also dominated the film. The idea was to give the viewer an idea of what was taught, how it was taught and of the reaction from the students. Students writing and drawing activities were also part of the film. The two teachers involved, were asked to validate the content of the video and both where positive. The class teacher said: "It is representing the progression very well and it gives a representative image of the activities and the learning situations- Yes, I think it shows the activities in a good way".

Each respondent was given a CD-ROM, consisting of the video together with a short background note about reading nature as a concept and a questionnaire with the questions discussed in the follow up interview. The interviews were semi-structured and followed guidelines from Kvale (1997). Each interview lasted between 50 and 70 minutes. The interviews were conducted by one of the researchers, the first author, and the analysis was done by both of the researchers. For reasons of transparency and hopefully of interest for the reader, the film is now available on mms://194.47.25.160/mna/vramsafilmen.wmv

Description of the respondents

There were altogether 13 respondents (1 male and 12 females, which mirror the distribution according to sex among the primary teachers in the municipality). The selection of respondents was made in cooperation with the local pedagogical centre in the municipality. The researchers asked them to select experienced primary school teachers without specialisation in science, but with interest and experience in outdoor education. Another criterion was that they should be reflective and willing to critically discuss learning and teaching issues. The respondents had at least 15 years of teaching experience and along with a majority of the primary school teachers in the municipality, they were familiar with the nature school and its methods and ideas. Six of them (R 1-6) were teachers with a part time engagement supervising or giving educational support to other teachers in the municipality. Their specialities were ICT, language or mathematics. The other seven teachers in the group (R 7-13) were teaching primary classes all the theoretical school subjects without any specialisation.

Space constraints make it necessary to present summaries of the respondent answers supplemented by the comments from three respondents in more detail. These three were chosen by the researchers since they had different challenges in their everyday teaching situation. Respondent 1 (R1) had long experience of teaching in an urban school with a mix of students from different social groups. The access to different ecosystems was limited and within walking distance it was restricted to parks or other "domesticated nature". Respondent 2 (R9) was teaching in a small school in a residential district. The near surroundings of the school were varied with access to several different ecosystems, such as rivers, forests and the sea, within walking distance. Respondent 3 (R12) had long experience from teaching in a school within an area dominated by multi-storey buildings and with a strong dominance of immigrants in the classes. Within walking distance they had access to small groves, small streams and open grasslands. The municipality is dominated by an open agricultural landscape with deciduous forests in the higher terrain.

The teaching sequence in outline

The teaching design had a bottom-up approach (i.e. starting with one organism and scaffolding an ecosystems understanding around this single organism). The key organism; a freshwater shrimp (Gammarus pulex) was introduced early. Its ecology was studied in some depth and its relations to other populations were investigated. This was followed by more abstract reasoning e.g. presenting models such as food pyramids or food chains, where the freshwater shrimp together with other organisms found were continuously referred to. Students' prior ideas were often challenged by the teacher or by peers when they worked in small groups solving different tasks both in the field and in the classroom. In general there was a mix of outdoor and classroom activities during every teaching event.

Phase 1: Autecology (i.e. the ecological relationships of a particular plant or animal species) ***of the freshwater shrimp***. The collection of the animal in the river was followed by an event of brainstorming when students were asked to come up with questions about the shrimp. These questions could be about its morphology or about functional or behavioural features which could be studied by observation or experimentation. The relevant questions and the conclusions from all the observations were summarised by the teacher on the white board.

Phase 2: Taxonomy: (i.e. identification and grouping of animals) and autecology. The class collected different organisms in fast and in slow sections of the stream and studied their adaptations to the environment. Herbivores and predators were determined according to their morphology and behaviour. Life cycles were discussed and in small groups the students made sealed aquatic ecosystems. The futures of these were discussed according to the roles of plants, animals and abiotic factors such as light and air.

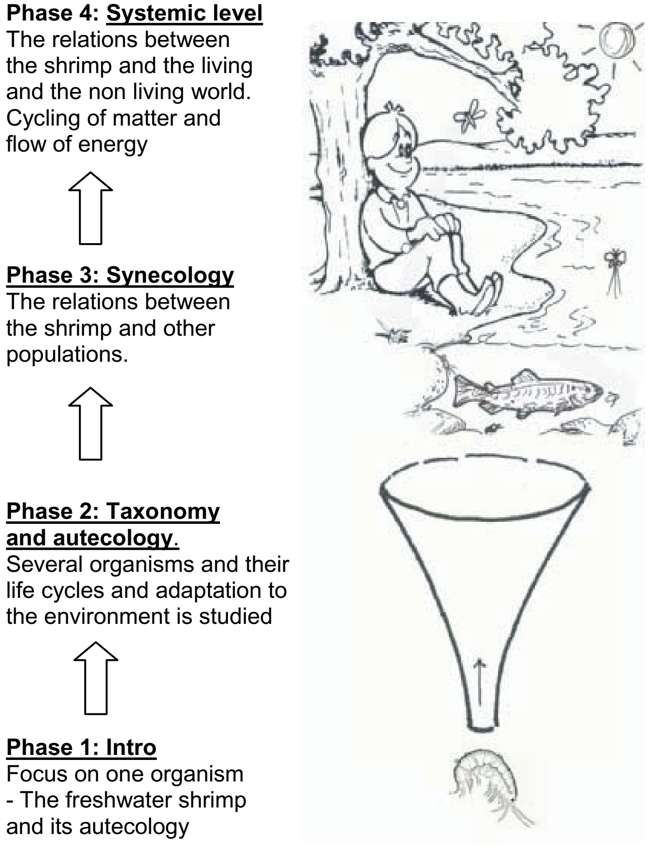

Figure 1. The teaching sequence from the freshwater shrimp to systems ecology and reading nature. The text describe the four phases in the bottom-up perspective.

Phase 3: Synecology (i.e. the ecological relationships of a community) was discussed and the students were introduced to models of food webs and food pyramids based on the organisms observed in the river. A litterbag experiment was conducted where the children put freshwater shrimps and water louse (Asellus aquaticus.) in small net-bags together with green and brown alder leaves. The bag was then put into the river. After a week it was collected and studied in order to find out if the animals preferred brown leaves and could be considered decomposers in the ecosystem.

Phase 4: Systemic view: (i.e. the relation between biotic and abiotic components and the flow of energy and cycling of matter in the ecosystem). A systemic view of the ecosystem was discussed and students were introduced to photosynthesis and energy flow in the ecosystem by discussing plants ecosystem functions and by building a model of a food pyramid. Photosynthesis and respiration was illustrated by LEGO pieces in an attempt to show that the same three types of atoms were cycling in the ecosystem. The sealed ecosystems were opened and examined. The relation between abiotic and biotic factors was discussed and investigated focussing on the importance of fast water flow for aeration of the water and the importance of trees both for the main food source and for the shadow keeping water temperature low and subsequently oxygen level higher. The importance of a varied bottom substrate for a higher biodiversity was studied together with the direct and indirect human impact on the river ecosystem.

Results

Two weeks before the interviews, the respondents received the CD-ROM together with a questionnaire. They were asked to fill in the questionnaire and prepare to discuss the questions. The three questions are presented together with an overview of all teachers comments together with quotes from the three selected respondents; R1, R9 and R12.

Question 1. The teaching sequence a)- what do you see as the most important factors influencing students motivation to learn in this teaching design? Rank your answers.
b)- what possibilities and problems do you see in implementing this teaching design in the everyday school situation?

Question 2. What is your view of the impact of the outdoor context for learning ecology?

Question 3. What is your view of 'reading nature' as a goal in science education?

1 a: The most important factors influencing students' motivation to learn in the film?
The list of factors varied in length between the respondents and we have chosen to present only the top-three factors from each respondents. As we see in the table 1 there were basically only three factors mentioned by all the respondents: The role of the teacher, the authenticity of the studied object and the structure of the teaching.

Table 1. Factors influencing students' motivation to learn.

Factor	Ranking	1	2	3
The teacher		8	3	2
The authenticity -"the real hands on experiences"		4	5	3
The structure of the teaching sequence		1	5	6
Other		-	-	2
	Number of respondents	13	13	13

The first factor mentioned by eight of the respondents was the role of the teacher. “He is a very inspiring person and he triggers their curiosity”(R9) or “He is very involved and he takes an active part in the activities supporting the kids, that is the main reason” (R12). The third respondent (R1) combined the importance of the teacher with the importance of the teaching design.

> ”What is actually going on in the film? –well, it arouses such a curiosity and they can observe and investigate. The teacher is most important because he asks questions and challenges them and their ideas all the time which is highly important. And also that you kind of revise the knowledge constantly by working in different contexts and in different ways with the same thing which is good and in the end you come to realise the whole. The teacher is most important but also the teaching design with the variation where you explore nature, read about it, have games about it and do experiments. This structure is very important”(R1).

The main reason for regarding the teacher as most important had to do with his ability to inspire and trigger students’ curiosity. Five respondents also mention the importance of him being a new acquaintance for the students. This novelty effect is well documented in other studies but normally declines after a few lessons (e.g. Gay 1987). The second most important factor for student motivation was the first hand experiences with nature. What R9 said was representative for most of the nine respondents considering this to be of highest or second highest importance: “It is so important to have the first hand experiences of reality- you have to go out and study the real thing- that is important”. This aspect will be discussed further in question 3. A clear structure is another argument where R9 said: “the bottom-up design is a wise way of doing it. I haven’t tried this but I can see that it works well”. The combination of enthusiasm and a well planned teaching sequence offering opportunities for first hand experiences are the most important factors according to the whole group.

1b: What possibilities and problems do you see in this design regarding its implementation to the everyday school situation?

In question 1 *b* they all noticed that the whole class seemed highly motivated for doing most of the different tasks they worked with, particularly in the early parts of the sequence, where the focus was on the animals and their autecology. In the interviews the respondents brought up five main aspects which could be viewed as either a support or an obstacle for this type of teaching.

Table 2. Different aspects supporting or hindering implementation of the teaching design in the everyday school. The aspects are listed in order of importance for the respondents

Aspects
knowledge and confidence of the teachers
quality of the surrounding nature
attitudes and motivation of the students and the teachers
curriculum
logistics and economy

All respondents discussed the importance of content knowledge (biology) and of the confidence and experience of field studies. Nine of them said that the most important for them was the confidence with the methods of outdoor education rather than content knowledge. They said they had enough confidence to try to follow such a teaching sequence. These respondents believed that lack of experience is the most important hindrance for its implementation in primary schools.

> "It is an inspiring method, open, and you are forced to engage in children thinking. Here are all possibilities but also obstacles because you never know where you will land. The teacher is very important. It takes a lot of the pedagogical- knowledge, commitment, inspiration. Without this it won't work. It is easier to tell this by the white board but then they don't learn very much. There has been a strong development among us teachers. From being restricted to the school book and teacher's desk it has changed. I work very differently today. For example, the lapwing, and how we now concentrate on one bird and look at it and draw it and find it in its habitat. This gives you other knowledge-more knowledge but you have to be much more alert. Knowledge is important but the key to it is to listen to the children and work with their questions. The knowledge of the method is most important. I am not a nature expert but I feel confident in doing these type of studies" (R9).

R12 agreed with R9 in the discussion about teacher knowledge but also stress the problems with students' lack of basic knowledge.
" It is more up to ambition than to knowledge. If you can be outdoors and you have the interest you will get far. But the teachers don't know how to do. That is the largest limitation. But today I have only three Swedish students in the whole class. I mean what is an elk? Yes, they don't know anything about our nature and that is a large difference. They haven't walked in nature with mum and dad. But in a school with fewer immigrants it is easier today than before to take the kids out if you want to" (R12).

All respondents argue for the importance of knowledge which gives the confidence to teach and the majority stresses the procedural knowledge and teaching experience as most important. As opposed to the respondents above, however, R1 together with three other respondents say that content knowledge is the most important.

> "It has to do with content knowledge more than pedagogical knowledge. My experience from seeing many classes and their teachers is that this is the most common reason for not going out".

In general this selected group regards their level of knowledge as a possibility rather than an obstacle for implementation in their school activities. One example of this is

> "If you are not a nature person you cannot do this type of teaching without training in it. It takes a lot of preparation, knowledge and commitment to make it work as it does in the film. You put a lot of effort into a few studies like the one in the film but you cannot do this all the time. You need clear goals and the most important is to give the children the opportunity to find the little, little thing and study it in great detail. This is how they gain respect for nature. You really touch them when you work like this. The limitation is probably that you really have to be committed to it and it must show that this is important to learn (R1).

Despite their own confidence regarding fieldwork, seven respondents were concerned about the general status in schools and particularly among the student teachers they met. This has implications for teacher training which will be discussed in the final section of this paper.

Quality of the surrounding nature

The second most common factor brought up was the lack of "high quality nature". The majority believed that many of their colleagues found this to be an important reason for not going out. Ten of the respondents said that they did not see this as a large problem for themselves. This is exemplified by the R9's comment:

> "In our municipality there are often good alternatives to the river ecosystem and with experience you can even study a school yard".

R1 said:

> "It is not the quality of nature in the first place, but it has to do with planning. We used to go out in a forest once a week but our students got bored in the 'real' nature because you, ee well you cannot expect them to just enjoy a walk in nature. You need to plan better than we did.

This refers back to the confidence and knowledge that can overcome the lack of access to 'real' nature, but for many teachers it can be of vital importance preventing field work, according to the respondents.

Attitudes

On the one hand it had to do with students attitudes where all the respondents commented on the high motivation of this age group. As R9 said: "The main possibility is that students at this age often find it interesting to do nature studies". The general view was that older students were less interested or at least it was harder to inspire them to do fieldwork, whereas younger students than these had to learn to be outdoors before it was worth starting with ecological theory. R12 referred again to immigrant students: "Many young pupils today compared to before are afraid of nature and this obstacle has to be overridden before teaching ecology can start, otherwise it is not fruitful".

Teachers' attitude was another issue. R1 together with three other respondents said that without knowledge and confidence it is very hard to motivate oneself as a teacher to do this kind of activity.

> "And it will not be successful if you are not highly motivated yourself. Since you have all the school subjects as a teacher you cannot expect all the teachers to love this part of their job"(R1).

Curriculum

All of the respondents referred to the curriculum as a support and not an obstacle for this kind of teaching. They referred to paragraphs such as "*students shall be familiar with the common plants and animals and their basic environmental demands*", or "*students shall be aware of the conditions for a good environment and understand basic ecological conditions for life*". They also referred to more open goals in the curriculum stressing the general school work where the students should meet different contexts for learning where they have to *cooperate, to discuss, to hypothesise, or to be curious.*

Their view was that basically all teachers in their municipality met the curriculum demand and taught about the common plants and animals in the nearest surroundings. Regarding the autecology the six respondents who worked as part time educational support believed that only a few teachers discussed the ecology of these plants and animals.

Six of the respondents were concerned about the recent change in priorities with a much stronger focus on the three core subjects Maths, Swedish and English. From compulsory school a pass in these three subjects is a prerequisite for upper secondary school. "In the schools today there is a priority on the three and that leaves the other less important. This can have a negative impact for the attitude towards this type of teaching" (R9). In line with this R12 said: "We work very much with the Swedish language now. This takes time from everything else".

Logistics and economy

When the respondents discussed possibilities they often referred to the flexibility in the school day in primary school. As an example R9 said: "Another possibility is that time is not limited at these ages and the schedule is not so structured. It is easy to find half days for these type of activities".

The respondents came up with examples of a practical kind and the major obstacle, mentioned by seven respondents, was that the classes were large and normally there was only one teacher in the class. Proper clothing was another common problem. One example was about rubber boots. "Some kids simply don't have them and then you can't force them to buy them and the school cannot buy them" (R1).

Two respondents spontaneously mentioned that they were worried about taking classes of thirty students out as a single teacher. The reason was not safety in the first place but had more to do with discipline.

According to the majority of respondents there are many factors in primary school supporting field studies. The flexibility in the time tables, the positive attitudes from students and the curriculum supporting these types of studies are some of them.

Lack of quality nature, lack of experience and interest in nature studies together with economical limits can on the other hand be insurmountable obstacles hindering fieldwork in some classes.

2: The importance of the outdoor aspect for learning ecology.
All of the 13 respondents argued that field studies are essential and necessary for ecology education in this age group. They often stressed the importance of the combination of fieldwork and indoor activities. This can be exemplified by the following comment:

> "both the outdoor and the indoor activities are important. To catch the animals yourself gives a completely different experience compared to if the teacher brought the animals to the class. But to work with the material is easier to do indoors and often students concentrate better indoors" (R12).

This comment also touches on the value of first hand experience which is an aspect of fieldwork. The three most important aspects are listed in table 3.

Table 3. The Respondents main arguments supporting fieldwork in ecology education.

First-hand experience
multiple senses
episodes

First hand experience and multiple senses
This argument has to do with the importance of studying the real thing and not second hand information in books or in computerized form. As R1 put it:

> "Yes, I believe it is very important to be both in- and out of doors for the understanding and for the feeling. You need first hand experiences. To touch it, hold it and listen to it and feel it. Otherwise I'm here and the nature is out there. If you have been out and tried this you can compare and you have references when you come out in different types of nature. Otherwise it will be as it was when I went to school. You studied the book and you copied things down in a workbook. You drummed it into your head and I can't remember anything of it today. But it is completely different in our schools today. Imagine all the time wasted by this way of teaching"(R1).

In this quote both the firsthand experience and the multiple senses are mentioned. If we compare the comments from R1 and R 9 below they hold the same features regarding first hand experience and multiple senses.:

> "You need to use many senses which you do when you are outdoors like on the film. You need to smell it and feel it to get a better feeling for the topic. It is easier to understand the ecology when you have been there- smelling it, seeing it and hearing it. You hook everything up in a different way when you experience it with all senses. You must have walked in the moss to be able to understand the forest (R9).

In the same vein R 12 said: "When you move indoors you loose the important context. Indoors you can never involve all the senses which are important for the learning".

These types of axiomatic statements are common. In follow up questions when the interviewer asked them to define why they believed this, they referred to feeling rather than facts:

> "Well it is my strong conviction but I cannot tell you exactly why. I mean that is just the way I believe it is. I haven't tested it. I mean who remembers a film? But when you have been out there and seen it live it is so different. I can only refer to myself and what I have seen in my classes" (R9).

These statements reveal some of the respondents' epistemological view where learning has to do with combining different sources of information and involving many senses. They also reveal an interesting view regarding the object of learning. As we see it their object of learning involved more than the theoretical ecological content knowledge. It also included the affective components, such as feelings, smells or fascination as part of the object of learning.

Episodes

Five of the respondents said that it is very effective to relate back to the outdoor experiences from fieldwork. They meant that these types of experiences are easy for the children to remember. One of the respondents referred to an event which may illustrate this.

> "as an example of how strong these memories are I recently met an old student of mine and she spontaneously started to talk about the memories of a field study event when the whole class studied the chaffinch. It was challenged by a stuffed chaffinch and a tape recorder playing its song. This was more than ten years ago and she remembered it clearly. And it was the first thing she said when she saw me" (R10).

If we look at what the respondents said about episodic memory. There seemed to be a consensus among the five respondents about the effectiveness of strong experiences from the outdoor environment for motivation and retention. It was expressed as:

> "You remember an experience more than just words. You get it home by experiencing it in reality. You need to know how it smells and feels in the forest before you talk about it. You need to be at home but it doesn't say anywhere in the curriculum even though we know that this is of key importance for this learning" (R9).

Along the same line R12 said:

> "When you have experienced it together you can always refer to it during teaching long after. And you can do it the other way round. I remember when we prepared for an excursion and I showed the class the yellow wagtail in the book and we talked about it. Then we saw it in the field and the class was stunned by its beauty and they talked about the bird often after that".

The stimulation of multiple senses together with fascinating experiences in nature was claimed by eleven of the respondents, to be of greatest importance for the learning and not the least for retention of knowledge. They believed that the film showed plenty of memorable episodes stimulating students' learning.

3: Reading nature as a goal in science education.
Reading nature is our own concept (Magntorn & Helldén, 2005) and as we defined it in the introduction it has to do with the ability to identify the organisms and to relate them to their ecology and their roles in the whole ecosystem. This demands for field studies and encompass relevant knowledge on the levels of taxonomy, autecology and synecology with ideas about cycling of matter and flow of energy in the ecosystem to be read. The main focus with primary school students lies in taxonomy and autecology but the other levels are also part of the teaching sequence and therefore part of the film.

Ten of the respondents found the aim of reading nature good or promising. Three respondents saw it as too difficult and too demanding. Among these three was R12 who said

> "we go out on our nature walk once a week and we study everything we see, not only nature. We look at the trees and sometimes birds or flowers but no, I don't link it so much to ecology. The focus is more on naming and recognition. But of course we could do much more of it like on the film but no I don't do that. I think it is much more complicated and maybe too difficult for my students".

What R12 said in the quote above echoes the response to question 1b where only six respondents believed it was common to discuss the ecology of the common plants and animals.In the excerpt below R1 discuss how to tackle the link between taxonomy and autecology:

> R1: "The film is a proof that it is possible to connect the organisms to their function. But I believe it is difficult for the teachers to do it. Yes, species knowledge is not valuable knowledge if you don't know anything about them. But I mean, look at the curriculum. It is easy to get stuck with species knowledge and not move further. // But I believe it is possible to follow the curriculum and also discuss the demands of the organisms. If you demand reading nature in the curriculum we might move from learning about nature to reading nature which is a big difference.
> Interviewer: How do you mean?
> R1: Yes it is not only about names and recognition but how to understand the whole, kind of. But the schoolbooks have to be a support. They have to be written to combine the separate parts in a way that helps the teacher to teach this way. Otherwise it would be too difficult. Schoolbooks today don't tie it together. They may start with the plants in the meadow but they don't tie it to ecology. This must change".

The most problematic part of the concept seemed to be the synecological and more abstract components or reading nature. All of the respondents had noticed a decrease in student's interest and focus when the teacher discussed and illustrated the cycling of matter. All thirteen believed this to be the most difficult part for the students but they had different views on whether it should be included or excluded from ecology education for this age group. In the excerpt below R1 expressed the idea that the principle of energy flow is worth mentioning but not the cycles of matter and the process of photosynthesis:

> "You need to know a bit to be able to discern the system. You need to explore the diversity first. You need to have names for the organisms before you can move on. After we have worked with the nature school about spiders or trees it is such a joyful expectation among the children when we are going out. Species knowledge and ecology should be linked but the question is when this linking should take place? I believe you need to do this all the time and it is not a bad idea to introduce the terminology and the more abstract processes early, like the energy"(R1).

Eight respondents (including R1 and R12) said that this is not relevant for these young students, since they believed they are not ready to learn this. Two of the respondents were not certain about this and three (including R9) said that they believed it was important to mention the concepts early hoping that some students gained from this when they were confronted with this theory in secondary school.

Discussion and implications

In such a small study as ours with teachers not chosen at random, questions must be raised concerning generalisation and application. The generalisations made consist of summaries and quotations interpreted and selected by the researchers. It has never been the idea to extrapolate and draw on the results as representative for a larger population but we believe the results can be useful if the reader can relate to them out of personal experience. The fact that there is often consensus or strong majorities in favour of specific views regarding didactical and practical issues adds to the reliability of the results from such a limited group of teachers. If we compare our results about the limitations and promises of fieldwork, with the findings in the large review of research on outdoor learning (Rickinson et al., 2004) there are some interesting points of difference. According to the review the main concern and fear was about young people's health and safety. Another major concern was the problem with access to nature. In our study the safety aspect was not mentioned by any of the respondents and the main view about access to nature was that it was possible to do fieldwork within the near environment of all the primary schools in the municipality. Why are there such differences in viewpoint? Regarding the quality of nature, this may well have to do with the varying degree of urbanization where the access to 'quality nature' in the municipality is relatively good. Another reason might have to do with the influence of the nature school where one of the fundamental ideas is to primarily study nature in the near surroundings of the schools. Despite their lack of specialisation in science the positive experiences from these nature studies might have influenced the respondents' attitudes towards field work even outside 'quality nature'.

Regarding the safety aspects in Sweden this debate has not at all been as intensive as for example in the UK and in the US. Tragic accidents during outdoor education in these two countries started a debate about safety, which has had a negative impact on the attitude towards all fieldwork (Rickinson et al., 2004). It is important to distinguish the wider concept outdoor education, which often holds aspects of outdoor adventures such as climbing or canoeing, from the type of fieldwork conducted in this study. In our teaching design the idea was to combine a strong focus on content knowledge with practical studies involving multiple senses.

Learning science means learning to talk science (Lemke, 1993). Each scientific discipline has its own semantics and learning to name the common organisms and to express relationships between the organisms and their environment is of key importance in reading nature. This literacy comprises not only semantics but also first hand affective experiences or as R9 put it to "feel at home" and to experience the river with many senses. The importance of combining affection and cognition is supported by Nundy (2001) who studied the relationship between affective and cognitive domains and concluded that gains in one domain reinforce gains in the other. Earlier in the paper we quoted one of the respondents mentioning a former student who after more than a decade still remembered clearly an occasion with a stuffed chaffinch and a tape recorder. This episode carried enough importance for the student to be integrated in her memory, or cognitive structures, for several years. This can be applied to the positive experiences from well prepared field work. The importance of fieldwork styles for long term memory structures was studied by Mackenzie and White (1982). The researchers found a positive correlation between fieldwork and learning in general but in particular they found that excursions or fieldwork which encouraged processing and produced strong linking of episodes with content knowledge improved students understanding in general but their long term retention of knowledge significantly. Narratives and personal relation to the scientific content is considered an important aspect of cognitive science and scientific literacy (Klein, 2006) and the concept reading nature certainly is an example of this. Reading nature has to do with discerning structures in nature such as plants, animals, rocks or litter, and to make up a relevant narrative about the ecosystem based on what they know about the ecology related to these structures in the nature to be read.

In the review mentioned earlier the curricula and the time table where viewed as hindering fieldwork (Rickinson et al., 2004). This was mainly the case in secondary schools, and likely to be the same in Sweden. In our study these factors were rather seen as support for fieldwork. In primary school in Sweden there is often one teacher in the class who teaches all theoretical subjects over at least three years. The Swedish curricula for science is, in comparison with National Science Education Standards (National Academy of Sciences, 1996) rather more open for interpretation and not as concrete and detailed. This leaves the teacher with less guidance and a more free hand in prioritising the content. The fact that students in Sweden get their first grades in year eight might also be an aspect where primary teachers can make their own priorities. The problems noted by the respondents were the lack of explicit stress on the outdoor environment as the place for instruction. The other concern dealt with a growing domination of the three school subjects, maths, Swedish and English. Several respondents saw this as a recent and rapid change affecting all other subjects in school. We see it as unfortunate if we move towards a three-subject school in Sweden, especially during primary school when the curriculum and time table open up for out of classroom activities and the young students are still enthusiastic about this.

Another major challenge according to the review (Rickinson et al., 2004) was teachers' lack of confidence and expertise in outdoor teaching where a study of Chicago primary schoolteachers' willingness to use outdoor natural settings for environmental education found that the teachers did not believe that they were particularly well trained to teach in natural areas. They believed their classes were too large to manage and that they lacked the necessary content knowledge to teach in such places (pp. 43). In our study the respondents also pointed at these challenges but it is interesting to notice that the majority considered their own methodological knowledge more important than the content knowledge. On the other hand they often assumed that insufficient content knowledge was the main reason for colleagues not doing field work like on the film.

The maybe greatest concern was the voices raised about the next generation teachers' lack of knowledge and of confidence in this field. This is supported by studies elsewhere. For example in the UK, Barker et al. (2002) point out that "the decline in fieldwork is also evident in initial teacher training […and…] in-service experience is becoming less likely". We believe it to be of great importance to involve both theoretical and practical aspects regarding fieldwork in teacher training. There is a motivated anxiety about fieldwork where several of the respondents stress the worry about loosing the control, a situation they find less likely to take place in the classroom. As Rickinson et al. (2004) stress, "Poor fieldwork is likely to lead to poor learning. Students quickly forget irrelevant information that has been inadequately presented. Fieldwork has to be well planned and executed". We believe it to be unfair to demand for fieldwork without giving the teachers the proper tools for it. Proper fieldwork does not only deal with environmental and ecological content knowledge but of course it also involves several other skills demanded for in the national curriculum such as cooperative skills and curiosity etc. Without confidence it is difficult to be the source of inspiration and motivation. We believe it to be important to include training in reading nature both as a concept, with its ecology content, but also as a method in the teacher training.

The combination of being competent in how to encourage and inspire students during field work has to be combined with the relevant ecological knowledge. One of the keys to successful instruction is that the teacher has enough experience to select the relevant organisms in the ecosystem to be read. Teaching for reading nature is not about describing all the things you find in nature but rather to help the students to discern the key organisms and the specific conditions governing the ecosystem to be read.

We also want to stress the importance of starting early with this type of instruction. As all the respondents have mentioned, this age group is good to work with. This is supported by a large study on students' perception of learning in natural environments where they found significant differences between the primary and secondary school age group where primary school students were found to be significantly more enthusiastic than their secondary counterparts both before and after the experience (Ballantyne & Packer, 2002). This enthusiasm together with the logistic advantage in primary school, mentioned above, support our belief that it is important to involve the young students in this type of education in primary school. It is easier and not less important to encourage their positive attitude towards nature at these early ages. Later on it may be much more difficult.

In conclusion we found that the majority of the selected teachers had experience based convictions about the importance of first-hand experiences, of involving many senses and of creating structured teaching events beyond just the naming of common plants and animals. The nature school seemed to be an important factor influencing this epistemological viewpoint where the method rather than the content knowledge was regarded as most important. The collected data suggests that teacher training should take into account of a range of factors and processes when encouraging students to be competent and confident users of field work in their teaching. Combining ecological theory with examples of successful teaching design and discussing the object of learning and the importance of the context for ecological understanding, as exemplified on the film, we believe are of great importance. A next generation teachers with a positive approach based on practical and theoretical experiences from teacher training is a very good start towards teaching for 'reading nature' in future classes.

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