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ENVIRONMENTAL LEARNING RELATED TO EARTH SYSTEM SCIENCE IN PRIMARY SCHOOL

Christel Persson

Abstract. *In this paper results from a longitudinal study, with 28 pupils in primary school, is presented. The question asked is how pupils develop concepts in a related to the natural- and the techno sphere. The qualitative research consists of interviews, questionnaires and video-recorded sequences in the pupils' science learning. The results were analyzed according to the Earth System Science model and the expressions were categorized according to their logical reasoning about what is happening between the spheres. The explorative study indicates the pupils' ability reasoning about solutions and developing their ontological views. It is a question about scientific facts and values. The overall conclusion is that the pupils over time are able to connect different environmental concepts and e.g. point out how toxic substances can be spread through the air into the water and the ground. Play and learning widens the perspectives and different explanations of concepts can be created.*

Key words: *Earth System Science model, play and learning, primary school, science education, sustainability.*

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Introduction

The results reported in this paper focuses on how young children in primary school develop concepts through out their science learning process. The aims of the research project are:

- to study how pupils in primary school (aged 9-11) develop concepts related to the natural spheres (air, water, soil and life) and to the technosphere.
- to investigate the pupils' development of words, expressions and games resulting from the dynamic interrelations occurring in and between the natural spheres and the technosphere.
- to discuss the significance of play as a form of learning about environmental issues, including man's position on Earth.

Research related to Earth System Science in primary school is a central theme in learning at different levels in environmental education. It is of importance that researchers and teachers in science education have knowledge about childrens' development of concepts related to the natural spheres as well as to society, the technosphere. Assarif and Orion (2009) claim that "a deeper aspect of environmental education includes the understanding that life influences and is influenced by- the natural environment and the natural environment is a system of interacting natural subsystems, each influencing each others". Learning through play is also an important area to investigate because of the lack of studies made in the area concerning pupils aged 8-11 years old (Johnson, Christie & Wardle, 2004).

In Swedish schools *Environmental Studies* and *Sustainable Development* are not classified as specific subjects. Instead they are listed as two obligatory perspectives in school education. As a consequence, every established subject, such as science, is expected to deal with environmental issues and sustainable development in the Swedish school system. Traditionally, educational research concerning environmental issues is concentrated on how different parts of environmental and sustainable development learning can be transformed into particular projects in established school subjects. Due to the substantial content within environmental studies and sustainable development education there runs the risk of marginalizing and replacing it by fragments from different subjects and didactics (Gough, 2002; Huckle & Sterling, 2001; Park, M.; Park, D-Y. & Lee, 2009).

Historical Background and Framework

When our environment changed at a faster rate in the 20th century because of pollution in the air, water and ground during the first period of industrialisation a new interdisciplinary subject dealing with smoke and water-pollution was established as health problems in factories and cities appeared in our part of the world (Sörlin & Öckerman, 2002). In the beginning, the concept of *environment* was identical to the concept of *ecology*. Linnaeus is often referred to as the first ecologist when he wrote about the self-renewing and self-cleansing nature being in balance in *Oeconomia naturae* (Broberg, 1978). The balance in nature was also accepted when Tansley (1939) in the 1930s introduced the concept *ecosystem*. The organisms in an ecosystem are usually well balanced with each other and with their environment. Even society was considered in balance with nature. Due to the increasing human population and changing lifestyle, the balance in nature is more and more questioned. Also, there is a rising concern about the impact of society on natural ecosystems.

The environmental problems led to a UN Commission with the former Norwegian Prime Minister Gro Harlem Brundtland in charge, who formulated the first definition of sustainable development in *The World Commission on Environment and Development* (1987).

> Development that meets the needs of the present without compromising the ability of the future generations to meet their own needs.
>
> (Brundtlandkommissionen, 1987, pp.43)

The commission widened *environment* to include a sustainable economy, technology and social welfare where, simultaneously, wildlife and nature is protected. The results formed a platform for the Rio-conference in 1992, *United Nations Conference on Environment and Development* (UNCED) as well as the Johannesburg conference in 2002 (WSSD). The Brundtland commission and the World Summits in 1992 and 2002 have influenced the research and education concerning the environmental perspective of sustainable development, including society and technology. UNESCO has also declared the period of 2005 - 2014 as *The United Nations Decade of Education for Sustainable Development* (UNESCO, 2005). Environmental studies are expressed as an obligatory subject for survival, which means that that learning about sustainable development cannot be fulfilled without specific didactics (Assarif & Orion, 2009; Gough, A., 2002; Park, M; Park, D-Y. and Lee, 2009). The results of *The Intergovernmental Panel on Climate Change* (IPCC) are also of importance to clarify the human impact on the environment (IPCC, 2007). In this perspective, the study is related to international trends. The global warming connected to the greenhouse effect are subjects of daily discussions in the media. According to IPCC, 2007, there is no doubt that global warming does exist due to human activities.

A human being has individual views on and relationships with nature and the natural environment. How we look upon man's position on Earth and the relation between man and nature may influence learning about the environment. Among others Alerby (1998, 2000) and Loughland et al. (2002) should be mentioned, who argue for a radical change in order to increase and widen the youngster's environmental understanding. I believe that a lot of people are aware of man's position on Earth and the role that he may play, but clarifications for children are needed. These dilemmas are also the ontological starting points in this study. One of the purposes of this research is to include the society as well as the natural ecosystems. In this study the pupils' words and expressions in their science learning, including play as an activity for learning, have been investigated.

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The Earth System Science Model

In order to analyse the pupils' development of concepts in science and sustainable development the sequences from the pupils' science lessons have been video-taped and the pupils participated in questionnaires and interviews. The purpose was to analyse the pupils' development of concepts throughout their science learning process related to environmental learning and sustainable development. A model inspired from *the Earth System Science*, *the Bretherton Diagram,* has been used (Bretherton's Diagram, 2006; ESS, 2006; ESSE, 2006a; ESSE, 2006b; Johnson et al., 2000; NASA, 1988) and *System Jorden* (Andersson, 2001). The model has a scientific approach which also includes human activities on Earth as examples. To explain the model of analysis for teachers and pupils it is necessary to transform the scientific terms to laymen terms: *The soil we set our footsteps on (the geosphere), The water we drink (the hydrosphere), The air we breathe (the atmosphere) and The life we live (the biosphere) using energy and material including the technosphere, which we have created* (Figure 1).

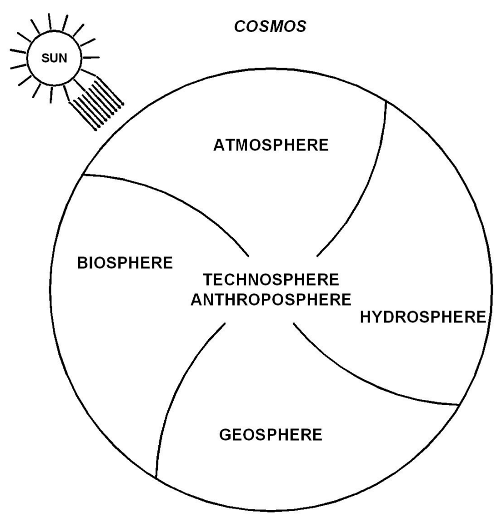

Figure 1. Illustration of Earth System Science, ESS, a simplified version after Johnson et al. (2000).

The model, which includes human activities on Earth as examples, gives the opportunity to study science and environmental issues through a holistic point perspective as well as in detail (Söderqvist, Hammar & Gren, 2004). Using the model it is possible to analyse the pupils' development of words, expressions and games resulting from the dynamic interrelations between the natural and techno spheres (Persson & Musidłowska-Persson, 2007; Persson, 2008). During the last twenty years *Earth System Science Education, ESSE* has been established to deal with environmental issues like *Where does pollution and waste come from? What will happen to it later? Where will it go?* (Johnson, et al., 2000).

Theoretical Perspectives – Play and Learning in Science and Environmental Education

The content in the following section is a theoretical starting point according to play and learning and learning theories in a longitudinal perspective. Persson (2008) stresses how the pupils' develop those concepts in the long run and how theses are related to the Earth's natural spheres and the technosphere as well as the open interactions in and between them. It gives an opportunity to study science and environmental issues from a holistic point of view as well as in detail (Söderqvist et al., 2004). With the model, it is possible to investigate and analyse the pupils' development of words, expressions and games in relation to what is happening in and in between all the spheres as a result of playing and learning.

In traditional subjects, e.g. physics, chemistry and mathematics, details are mainly learned first, but studying environmental science also needs a holistic and system thinking approach from the beginning (Assaraf & Orion; 2010; Sjøberg, 2005). The relation between details and the 'understanding the big picture' (the defined system) is also a subject of philosophic thinking (Wittgenstein, 1992; von Wright, 2000). If you analyse the details and the 'defined system' at the same time, you may find the functions and the interactions between all components (Carlsson, 1999; Ingelstam, 2004).

Learning through play is integrated in the physical learning contexts. Both mimesis and mythos have advantages to be linked together with the Socratic dialogue and the metacognitive phases of the pupils' development in current questions (Rasmussen, 2002). The pupils change their views and perspectives from storytelling (mythos) to performing the content (mimesis). In all contexts, the Socratic and metacognitive dialogues are important. The *Socratic dialogue* is based on reasoning and logical discussions in which the leader of the dialogue does not reveal the answers (Molander, 1996). This philosophy is based on gaining knowledge through common sense mediated through dialogues (Guthrie & Keith, 1999; Molander, 1996; Taylor, 1939). In the Socratic dialogue the teacher asks questions and the learner needs to look for the answers and possibly create new questions. Unique to studying sustainable development is the possibility that more than one answer can be the right one. *Metacognitive dialogues* are used above all in research that studies children's ability to understand others' perspectives, called *Theory of mind* (Astington, 1998, Pramling Salomonsson & Asplund, 2003). In the outdoor education centre, learning with both body and soul is emphasised (Cornell, 1998). *Play and learning* are integrated simultaneously in all physical contexts.

Learning Theories of Relevance for the Longitudinal Study

According to Bruner, (1960, 1996) one must understand concepts and structures connected to real life. At an early stage, he observed education based on abstract as well as practical conceptions and connections. Due to age and maturity there will be a progressive development in learning which is important in a longitudinal study. That is what we know as the spiral principle (Bruner, 1960, 1996). The spiral principle is used to make children aware of concepts after repeating the same ideas from time to time in increasingly advanced forms. The concepts must be presented in similar ways, since the pupils will meet them in everyday life (Bruner, 1996).

Of relevance is the conversation in the classroom according to the classical dialogue of Socrates and by the importance of communication and language analysed by Bruner and Vygotsky (Bruner, 1996; Vygotsky, 1986). The process that enables a child to solve a problem with help from an adult, scaffolding, is one part of my theoretical basis (Bliss, 1996; Bruner, 1996; Vygotsky, 1986). I have also taken part in what is called exploratory talk (Alexander, 2006), which is also known as a critical dialogue. Alexander (2006) promoted the discussions and arguments in science and environmental education, as well as the meaning (Ausubel, 1968; Helldén & Solomon, 2004).

Finally Dewey also inspired me in the research when he strongly promoted participation, shared experience, and shared interests being important in the classroom as well as in the democratic society (Dewey, 1916). The theories used also refer to the teacher's and children's ability to meet and use scientific models according to van Driel and Grosslight (Grosslight, Unger, Jay & Smith, 1991; van Driel & Verloop, 1999).

The ESS- model is connected to Wittgenstein's philosophy of language-game as well as Bruner's ideas about how children structure their own knowledge according to the spiral principle. An important point in the analysis is to distinguish the pupils' answers dictated by the laws of nature from the answers related to the technosphere/anthroposphere. In the anthroposphere technical, legal, economical and political perspectives are included.

Methodology of Research

The paper is of an explorative nature and a qualitative methodology has been used. The approach of the methodological theoretical framework arises from a social constructivist viewpoint. Learning is a constructive art of the learner and at the same time as the learner is active with the teacher and the other

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pupils in the class room (Andersson, 2001). The described study took place in a Swedish primary school consisting of 28 pupils who were nine years old when the longitudinal study started. The investigation concentrated on the pupils' learning in science, which is led by a science teacher. The research focused on a class in primary school, where the pupils and their teacher naturally met at different arenas during the science lessons. The physical places where learning took place are in the classroom, in an outdoor education centre and in nature.

The research question for the study is:

How do pupils in primary school develop concepts related to the natural spheres on Earth and to the technosphere/anthroposphere in their science learning?

The aims are:

- to study how pupils in primary school (aged 9-11) develop concepts related to the natural spheres (air, water, soil and life) on Earth and to the technosphere.
- to investigate the pupils' development of words, expressions and games resulting from the dynamic interrelations occurring between the natural spheres and the technosphere.
- to discuss the significance of play as a form of learning about environmental issues, such as man's position on Earth

The longitudinal study started in a 3rd form of primary school, with 29 children, in a city in southern Sweden. The children also worked with outdoor education and attended excursions. Play and games also were a major part in the pupils' science learning.

Methods and Samples

The data was collected using the same procedure for three years, or six semesters. One of the 29 pupils moved from the city. With this in mind results of 28 pupils are presented. The study started with videotaped science lessons and questionnaires completed by all of the pupils in the class and ended every semester with semi-structured interviews of ten pupils. The method *stimulated recall*[1] was carried out twice giving the teacher an opportunity to comment on some videotaped learning sequences and answer some questions concerning the lessons (Table 1.). The selected criteria are described below in Section "Questionnaires and interviews". Both the video recordings and the interviews were transcribed verbatim. This research design made it possible to get a holistic picture of the pupils' science learning according to their development of concepts related to the natural spheres on Earth and to the technosphere/anthroposphere. Generalization and validity have been taken into consideration in the study. During the study there have also been collected parts of the pupils' notes and drawings.

Table 1. Overview of the data collection and methods.

	Autumn 2003	Spring 2004	Autumn 2004	Spring 2005	Autumn 2005	Spring 2006
Questionnaires (28 pupils)	X	X		X		X
Interviews (10 pupils)	X	X		X		X
Video observations	X	X	X		X	X
Stimulated recall with the science teacher		X	X			

1 *Stimulated recall* is used in order to find out the reaction of the teacher during the lessons too. The teacher had to comment some videotaped sequences in the classroom and answer some questions concerning lessons and communication in the classroom and outdoors.

Video Recording

The most important argument for using video-recording as a method in this study is the possibility to catch the free flow of words, expressions and games in the pupils' science lessons. In order to analyse the communications among the children and the teacher video-taped sequences and interviews took place and were transformed into transcripts. Video recording was chosen as a method instead of structural observations because by video you are able to capture the real activities without interfering with pupils interactions (Jordan & Henderson, 1995). The video recording is a method that better transforms the real world and pupils' activities.

Questionnaires and Interviews

The questionnaires were open-ended and answered by all the pupils in the class. Ten of them also answered the questions in the semi-structured interviews. The questionnaires took place four times: in autumn with the 9 year olds, spring and autumn with the 10 year olds and spring with the 11 years old. In the questionnaires the pupils had the opportunity to answer spontaneously with words, sentences and drawings. Individually semi-structured interviews have continuously been carried out with the young pupils. Interviews were chosen as a method to complete the video-taped sequences. The interviews were semi-structured with open-ended questions relating to the concepts in the video recording. During the individual interviews different objects were shown to the pupil, e.g. a toy car, a book with pictures illustrating photographs of landscapes. These kinds of interviews initiated the conversation as the pupil related to the objects (Ginsburg & Opper, 1988). During a more structured interview there might be a risk of losing what was on the pupil's mind at the moment it was carried out.

Examples of the questions asked were:

> *In what way is rain created? The teacher has poured water in the sink. What will happen if it will not be dried at once? What do plants and animals need to live, Look into the bag. This is soil taken from the compost. How can it become soil in the compost? What happens with the contents in the toilet when you flush? Where does the tap-water come from? What happens when oil goes into the sea? Why do we sort waste? Why do we collect batteries? How will corrosion happen? What do you mean by a bus being adapted to the environment? What is the difference compared to a traditional bus? How does a greenhouse work? Have you heard about the greenhouse effect? What is it?*

Stimulated Recall

The method *stimulated recall* gives the teacher opportunities to comment on the work. *Stimulated recall* is also important in order to find out the reaction of the teacher during the lessons too (Calderhead, 1996). The teacher had to comment on some video taped sequences in the classroom then answer some questions concerning lessons and communication in the classroom as well as the outdoors. The criteria for selecting the video sequences were 1) one from every moment that had been video taped and 2) in each video taped lesson 15 minutes were collected at random. *Stimulated recall* is also a useful method in order to remind the observer about what a person was thinking during a certain episode. It is possible to look at the collected data from a different point of view.

The Analysis

Data collection comprised 30 hours of video recorded lessons in science, without the researcher setting the frames. The answers from questionnaires (1176) and semi-structured interview answers (420) were compiled. Four hours of interviews by the science teacher were also included in the data collection in addition to the documentation of notes, drawings and narratives from the pupils. The researcher worked out the questionnaires and interviews after carefully reading the written empirical material and then transferring it to word documents. The results have been analyzed according to the

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Earth System Science model (ESS, 2006; Johnson, et al., 2000), and the pupils´ words and expressions have been categorized according to the natural spheres in more or less complicated ways. Or they were expressed in logical reasoning where human beings were included. The categories for the analyses are not hierarchically designed. In this study presentation of the pupils' development of concepts are presented in groups as well as individually. Interviews from *stimulated recall* were transcribed verbatim in the same way as the other interviews in the study.

The categories described in Figure 2 are based on the pupils' answers in the way they were expressed in the video sequences, questionnaires and interviews. Category A comprises the pupils' answers expressed by single words or expressions that excluded from relations and connections related to the natural spheres and the technosphere.

Categories B1 and B2 comprise expressions that contain interactions related only to the natural spheres. In category B1 answers are expressed through simple natural causal relations, while category B2 contains more complicated expressions that consist of interactions in and between the different natural spheres.

Categories C1 and C2 contain answers that include expressions which can be related to the natural spheres, but also to the technosphere/anthroposphere. Category C1 comprises simple connections and relations related to the natural spheres and the technosphere/anthroposphere. They are simple connections and relations where human impact on the natural spheres is part of their expressions. Finally, category C2 contains the most complicated connections related to the natural spheres including the technosphere/anthroposphere. Category C2 is the most sophisticated level in the category system in relation to the scientific and environmental framework in this study.

The categorisation is in no way hierarchically built. It has two forks, pathway B1-B2 and pathway C1- C2 (Figure 2). It is not a linear categorisation; instead the categories are integrated with in each other, e.g. the increasing green house effect (IPCC, 2007; Jonsson, 2007). Causal relations in the natural spheres, the pure ecosystem, circulations and other flows in nature can be illustrated by mathematical terms as $X_1, X_2, X_3, X_4, \ldots X_n$, which can be summarised as the answers categorised as A, B1 and B2. Since human impact – or human as a society builder – makes ecological footprints on the natural spheres, the pure ecosystems and flows will change. The number of variables in the mathematical model will increase to additional dimensions – technical, political, economical and even more unknown variables. The pupils' expressions then are analysed as A, C1 and C2. One step in the analyses is to try to visualise the pupils' views of the world and the spheres that are prone to change.

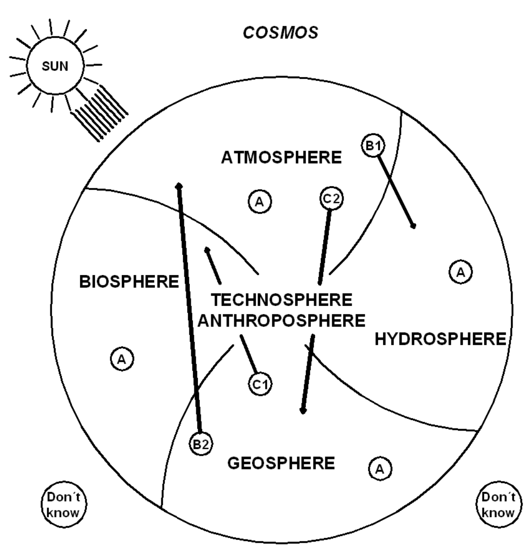

Figure 2: Illustration of *Earth System Science, ESS*, a simplified version after Johnson et al. (2000) with examples included. A, B1, B2, C1 and C2 are the different categories.

Results of Research

In this section the results of the study are presented with examples from the pupils' words, expressions and games.

The video-recorded sequences are important in the study because they enabled me to catch the pupils' development of concepts as unbiased as possible. The concepts for the analysis were not decided from the beginning. The questions for the questionnaires and the interviews have been constructed with the video-recorded lessons in mind and the concepts that have been treated there. When "new" concepts appeared during the lessons, suitable new questions in the questionnaires and the interviews were added. Also, all the questions were adapted to the young pupils' level. The results showed that several different concepts were connected into a network, or a 'concept web'. The concepts identified during the science lessons are as follows:

The hydrological cycle, life, soil, water in every day life, pollution, waste, batteries, corrosion, non-polluting busses, greenhouse and *the increasing greenhouse effect*

Formation and Development of Environmental Concepts

In the formation and development of the pupils' concepts different trends can be discerned, as described by the categories B1-B2 and C1-C2.

In conjunction to the concepts, *water* and *soil* some questions were asked: *In what way is rain created?* and *How can it become soil in the compost?* The pupils' answers were mainly categorised as B2. The pupils developed concepts dealing with *water in every day life; non polluting busses* and *waste* that were generally categorised as C1 and C2. According to concepts such as *pollution; corrosion; collecting batteries; greenhouse and the increasing greenhouse effect* the answers of the pupils were classified and categorised as B1 and B2 as well as C1 and C2. There are several examples in the empirical data collection illustrating this kind of *conceptual conflict* where the categories in the pupils' expressions are integrated in each other. What plants and animals need for survival can be classified as A with the trend category B2 and the question about the water being left in the sink as trend B1.

There are concepts that the pupils stated as quite scientific. *In what way is rain created?* and *The teacher has poured water in the sink. What will happen if it will not be dried at once?* are two questions which illustrate concepts that we regard as pure scientific. On the other hand there are other concepts that the pupils in their answers relate to human activities, society and technology.

The results describe the problematic situation concerning e.g. *What is the increasing greenhouse effect* where even adults debate about the natural and anthropogenic causes. Questions about concepts such as *life; the increasing greenhouse effect; batteries; pollution; non-polluting busses* and *water in every day life* were answered by the pupils comprising terms related to atoms and molecules. The answers also were expressed using physical and chemical explanations – as in the following examples (Table 2.).

Table 2. Examples of the pupils' expressions concerning the increasing green house effect.

Bob (Category C1- 10 years):	"Yes it is when there are exhausts and things like that. For example oil. It becomes air pollution and it is not good. It turns to exhausts and it can be warm like in Paris the other year. It can, as some people say, become climate changes."
Bob (Category C1- 11 years):	"Well, it is from exhausts. It will be warmer. It will be spread into the atmosphere and make a hole in the ozone layer. More sunbeams will reach us and the temperature will get higher."
Sonja (Category B2- 11 years):	"It is when it is getting warmer and warmer and then the ozone layer will be destroyed and intense sunbeams will enter the atmosphere. I think this is the increasing greenhouse effect. There will be a hole in the ozone layer and the molecules will destroy the ozone layer."

Several pupils made connections between different concepts and pointed out toxic substances and pollution that spreads in the water that we drink and into the ground from things like batteries and motorized vehicles (compare with the Earth System Science model, Figure 1, and Figure 2). They do also mention realistic scenarios for the future. Generally there was an obvious conflict between Pathway B

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and Pathway C concerning concepts such as *What is pollution; corrosion; collecting batteries; greenhouse and the increasing greenhouse effect*. Examples exemplifying the first two laws of thermodynamics were common in their answers as well as in the health perspectives. The majority of the pupils also expressed that pollution from vessels kills fish and birds in the first place, but not humans. Several of the pupils also mention technical solutions in order to avoid environmental problems in the future saving natural resources e.g. the forests, sand and minerals on Earth.

The following interview-transcripts (Table 3.) appeared from Sonja's, Hans' and Bob's interviews (10 years old) talking about the exhausts in the air. They point out *where the pollution comes from, how it will be spread* and *what we in some way are able to do about it*.

Table 3. The pupils' expressions concerning environmental friendly vehicles.

Sonja (Category C1):	"The exhausts will go up in the air. It is in the air. It is everywhere. It is not good for the animals and not good for us. Our lungs can get sick. The plants can feel bad too. Instead you can have bio-gas or rape oil that is not poisoning the environment. If you do so you have used things growing in the nature. And it is not dangerous."
Hans (Category C1):	"Electric cars and biogas. That is what the plants are used to. Animals and plants can get sick. The exhaust is not healthy. There is some pollution in it. You can have electric cars or gas from the garbage dump or from rice fields. Much better exhausts than the one from petrol, because the nature and the environment is used to it."
Bob (Category C2):	"In the tank the cars have petrol so when the exhausts come out there will be carbon monoxide and carbon dioxide. Last summer it was very hot in Paris. Some people say it was because of the exhausts that contribute to climate changes. The petrol looks like water. You can have electric cars. It will not pollute so much and it is not so dangerous. Next time we will buy a car that is good for nature."

Play and Learning in the Science Lessons

One video recorded lesson took place on the beach when the pupils were 10 years old. The teacher used play activities as a method for her science lesson. Theoretically there are a lot of definitions concerning *play*. In this research the focus of play contains the following steps:

1) What the pupils already know – the pupils´ status of pre-knowledge
2) Instructions for play activities
3) Performance (mythos)
4) Metacognitive dialogues (reflections) – a storytelling (mimesis), with *theory of mind* included

The Pollution Game

First the pupils were placed in a circle in the sand. They started repeating what they already knew about food chains and food webs. In the actual game the animals were small fish (perch), bigger fish (pike) and a bird called fish eagle (osprey). Simultaneously the pupils individually were asked to draw food chains on a paper and here follows an example of one dialogue.

Teacher: A pike eats at least more than one perch and there are only two fish eagles in the play. How is that? How could it be? There are less of the kind of animal that are on a higher level in the food pyramidal. From where do the small fish get their food?
Otto: Plants.
Teacher: And from where do the plants get the food?
Otto: The light. The sun.
Teacher: The light and the sun. That is correct. And a bit of water too.

Concerning the concept "life" the pupils developed a concept web based upon the photosynthesis. The teacher had put different colours of pasta screws in a square of 75-100 square metres in the sand. The next step in the play activity was to give the pupils practical instructions to the activity.

Each pupil got a little paper bag. In the game the 18 pupils acted as small fish and their task was to collect as many screws of pasta as they could in 30 seconds. The paper bag symbolized their stomach. Then eight pupils, acting as pikes, will appear in the square. Their aim was to hunt the small fish in about 15 seconds and take over the paper bags containing the pasta screws as their own. The captured small fish were placed outside the square while the others stayed in the square. Finally the fish eagles (in this activity there were two) had 10 seconds to hunt and eat the pikes. Every new section of the game was led by the science teacher by a wolf whistle. Then the pupils counted the number of pasta screws they finally got in their paper bags and compared with another. In such a play activity the pupils meet and are a part of both mythos, where they do act as different organisms, and mimesis, a part where they talk about (in a storytelling) their experiences from acting as a perch, pike or a fish eagle.

Then the teacher added the following information:

Teacher: If you are a small fish and have more than seven red screws of pasta in your paper bag then I have to tell you that you unfortunately died in this game. This because there was a vessel in the sea that had an oil discharge. Pikes that had more than 21 red screws of pasta will also not survive.

Björn spontaneously exclaims: I survived, although I died!

In the last part of the activity they discussed the number of red pasta screws the fish eagle can survive with and the reasons for that.

Teacher: It is not only the animals that will be poisoned by the discharges. It will affect our lives too. All the small fish died, there was nobody left. How about the pikes? Did any of the pikes survive?
Peter: Yes.
Teacher: Some of them did. Do they have any food next year?
Peter: No.
Teacher: How will they manage next year?
Peter: They will die of course.
Teacher: They will die, here in this game. I really hope it will not get that bad in reality. How about the fish eagles? Do you think they will survive eating more than 21 red screw pastas?
Tim: Yes.
Teacher: That is right, Tim. Why?
Tim: They have a big stomach.
Teacher: Yes, and when thinking about the food chain, in what level are the fish eagles?
Tim: At the top. The highest.
Teacher: The higher level on the pyramid the organism is placed the more concentration and enrichment of poison it has. The fish eagle can manage 40 red screws of pasta. How many of you who acted as fish eagles have more than 40? Actually they will not die, but their eggs happen to get thinner and when they sit on them they get broken. Can there be any new birds then?
Pupils: No.
Teacher: What is the reason why the fish eagle did not get any more children? What was the reason from the start?
Mary: It ate poison. Got oil in itself.
Teacher: And who were most affected?
Pia: The animals. The small fish and the pikes.
Teacher: Both the small and bigger fish. What animal was most affected in our play activity?
Jenny: The small fish.

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Results from Interviews and Questionnaires

The question*: What happens when oil gets into the sea?* was problematic for the pupils and confronted them with the natural cycles and how they are interconnected.

Answers from questionnaires over time to the question: *What happens when oil gets into the sea?*
Example category B1 in interview (Mary, 10 years old).

Mary: It is not good for the fish and not for the birds. If they get it in their feathers they will die.

Example category B2 in interview Otto (11 years old).

Otto: All animals, you know. The ducks and their bills (beaks) and feathers will be sticky so they can't move or do anything, so they will die.

Interview category B2 (Sonja 12 years old).

Sonja: It is not good. The poison will sink to the bottom after a while and animals and plants there will die. It will be spread into the water too. We can survive but when the water evaporates later… The poison will perhaps also evaporate and get to the clouds, and then it will turn to rain again.

The pupils' answers emphasised that their view of the pollution is that it is enriched in the food webs, but at first only animals were affected.

The Teacher's View- Stimulated Recall

The science teacher pointed out difficulties of learning about the environment, but from time to time she takes examples from everyday life. She was consequently using an inquiry method. She seems to be aware of the spiral-principle to Bruner (1960, 1996), but hardly familiar with Socratic dialogue. Regularly, the teacher discussed the problem of environmental studies teaching is the difficulty of finding only one right answer to environmental issues. There are, she said, environmental concepts and facts, but there is also space for values. She was also aware of the possibilities to use every day concepts and transforming them into use in science teaching. She changed her teaching spontaneously from a holistic perspective to a more focused perspective and vice versa, illustrating the Earth's model. Her comment after looking at video sequences that showed this behaviour is:

Teacher: It was not my intention to change between micro and macro level from time to time. It just happened.

She also expressed her intentions concerning the choice of methods used in her science teaching. Her comment is that although the pupils do not know everything about certain content, they have heard it and in another time and place they will develop this knowledge step by step.

Discussion

In this empirical study it appears that *the hydrological cycle*; *life* and *soil* and several other traditional concepts used in science belong to the culture of knowledge, named environmental education. It is also clear that *water in every day life; non-polluting buses; other waste including batteries; pollution; corrosion; greenhouse and the increasing greenhouse* effect, also belong to the environmental education culture. In the analysis with the Earth System Science model (ESS), the basic level A contains words, simple expressions and play activities that are usually everyday expressions. Though they should not be ignored or ridiculed. It is also important that the pupils' development does not end at a basic level. Instead environmental education should offer possibilities to the pupils to express and debate using pure scientific connections and relations including concepts such as the technosphere and the anthroposphere. Hence, these words and expressions should belong to the environmental education culture.

The ESS model is connected to Wittgenstein's philosophy of language-game as well as Bruner's ideas about how children structure their own knowledge according to the spiral principle (Bruner, 1960; Wittgenstein, 1992). An important aspect of the analysis is to distinguish the pupils' answers ruled by the laws of nature from the answers related to the technosphere/anthroposphere. In the anthroposphere technical, legal, economical and political perspectives are included. This is especially shown in the answers from the pupils when the starting point in the interviews concerns environmental vehicles and the increasing green house effect.

The young pupils in this study, however, takes part in nature and society in this way dealing with environmental issues. Most important is how they are using environmental concepts to describe and understand what is happening in the soil, water and air and how this will affect our lives. The play activities do in my point of view influence the pupils in a way according to Bruners´ spiral principle: Their experience ought to be transferred to as many situations as possible. As a part of the play activity, the metacognitive dialogues develop the pupils´ logical reasoning to be able to find solutions in difficult and interdisciplinary issues (e.g. compare p. 15-16). The model related to the Earth's system also gives possibilities to handle questions like: *Where does pollution and waste come from? What will happen to it later? Where will it go?* Those are questions arising from the knowledge that nothing disappears and everything is spread out.

During play activities new perspectives and different explanations of the concepts can be created (Lindqvist, 1996). Rubin refers the phenomenon of play to Piglet's' theory of steps where play activites depends on the children's' age and maturity (Rubin, Fein, & Vandenberg, 1983).

Stimulated Recall

The obtained results indicate that the Socratic dialogue is a possible and successful method to use for the development of pupils' concepts in environmental questions and issues. A significant advantage of this method is the opportunities it allows for the pupils to take part in logical reasoning where the dialogues pose new and important questions. This is imperative in environmental education and learning, since there is often more than one correct answer (Guthrie & Keith, 1999). There are, she says, environmental concepts and facts but also there is space for values. The teacher is also aware of the possibilities of using every day concepts and transforming them into scientific concepts. The teacher spontaneously changes her teaching from a holistic perspective to a more focused perspective and vice versa, illustrating the Earth's model. Her comment after looking at video sequences supports this behaviour:

Teacher: It was not my intention to change between micro and macro level from time to time. It just happened.

It is possible for the dialogues described to occur when in a safe and comfortable class-room atmosphere together with a teacher who both has a genuine interest in these issues and has the scientific as well as the pedagogical and didactical competence.

The empirical study shows the pupils' ability to talk about solutions for sustainable development and their different ontological views. When studying the pupils' words and expressions I have found that there is an obvious conflict between man and nature. The pupils for example put focus on birds and fish when they are talking about an oil spill in the sea. They do not seem to be aware of the possible consequences an oil spill may cause them. They do also express in what way it can be possible to save natural resources.

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Play Behaviour and Learning in Science Education

When the young pupils act as different organisms in their play activities and other games their logical way of thinking is developing. The communication in the learning situation becomes very important (Alexander, 2006; Bruner, 1996; Helldén & Solomon, 2004; Vygotsky, 1986). Development of concepts and knowledge are two different research areas. The first step to achieve knowledge and reach the established goals stated in the curriculum, however, is to develop concepts. In my study, there was a spectrum of different ways where the pupils' develop different concepts, e.g. *the hydrological cycle; soil; life; corrosion; non-polluting buses and global warming caused by the greenhouse effect*. Of course there must be a connection between the pupils' learning and their individual development. A question to ask concerning this matter is for instance: what different possibilities does the teacher have in order to obtain continuity in the pupils' individual development in groups with 28-36 pupils compared to classes with 15-20 pupils?

The formation of concepts analysed in this study can in some cases be identified as *conceptual changes* (di Sessa, 1988). The pupils change their answers and expressions quickly from one year to another, while there are also examples where the pupils use parallel explanations, both from pathway B and pathway C. *Conceptual growth*, which is identified as a more stable development, is also identified in the material used in the analysis (di Sessa, 1988).

Discussion Concerning Methodology and New Questions for Research

The teacher in the class and the pupils were picked at random in south Sweden. As a complement to this qualitative study I have asked identical questions in questionnaires and interviews to pupils in other parts of Sweden, but of the same age. They were selected at random. The results show that these pupils use the same words and expressions as in the investigated group. With this additional data the methods of data collection have been tested. In literature and earlier research (e.g. Helldén & Solomon (2004) similar methods have been used in studies concerning science education. In this case, I have chosen the Earth and the spheres as a model for analysis, which even younger children can understand when they stand on the ground, breathe the air, drink water, use technology and reflect on how they live.

The analysis instrument requires a detailed description of the category system. As a researcher, I have consulted a group of researchers in science and environmental education to test and verify the ESS categorisation. The agreement is 90-95% according to the categories A, B and C and 75-80% according to the categorisations A, B1, B2, C1 and C2. After consulting my colleagues the instrument for categorisation have been somewhat reversed. The quality of the instrument for the analysis fulfils the goal of investigating a causal as well as linear and integrated learning. The system for the analysis also achieves the goal of creating a generalization concerning the imitation of reality, the accuracy of data measurements and transferability. The model probably then has to be modified at the analysis of the answers from older pupils.

For further research it would be interesting to investigate some critical points when the play activities are taking place. Even the teacher's different ways to deal with values of play and games behaviour in relation to the Swedish curriculum would be of great interest to study. The metacognitive phase of the pupils' learning, according to pathways B1, B2 and C1, C2, is also important to further analyse. Additional research would be very interesting to find out how young children can use environmental concepts and conceptions when discussing more and more complicated environmental issues, and even propose solutions in science as well as in other subjects. Lastly, the scientific and longitudinal approach used in the study is worth following up to observe what will happen when using this model on older pupils.

Conclusions and Implications

The *Earth System Science* is a valuable tool that will become even more useful in the future in order to develop education and learning in environmental studies and sustainable development. It is very likely that traditions in environmental education research and sustainable development will change.

It is very important that teachers and researchers in environmental education as well as decision-makers on several levels in the society, especially in the education area, have knowledge about studies like this. The pupils do have a good logical way of thinking about these questions that every educator has on their mind. It is very dangerous if the education including dialogues with the children, in this area do not involve the context of society (category C) according to the ESS-model. Viewing facts as basic knowledge necessary for constructing and developing attitudes and lines of action in environmental and existential questions are very important in the future. It may be necessary to reconsider and give priority to the research area: Environmental Didactics. Today the work towards sustainable development has been more urgent in learning and education due to more frequent environmental problems (UNESCO, 2005). The data collection in this study was observed from within the pupils' science learning of an established Swedish curriculum, aged 9 to 11 years old. The obligatory perspectives of environmental learning and learning about sustainable development are fixed parts of the curriculum too. The results of the study show that it is possible to bring both perspectives into the science lessons and at the same time obey the established curriculum. Notable is that *Play behaviour and learning* today has an important role in the Swedish curriculum and is explicitly formulated as a goal the pupils ought to meet in their education (Pramling Samuelsson & Asplund, 2003).

It is also interesting how very young pupils understand the needs for changing technology as well as attitudes and lifestyle. The teacher stimulates the communication in the classroom. In many cases the dialogue continues outside school, when children are talking with their parents or other adults.

The suggestion of the results of this study is that we need to start with science and the environmental perspective within learning for sustainable development very early in school, since the results of this study indicate that the pupils' formation of different themes and development of environmental concepts starts in their early years (Assaraf and, Orion, 2010). I also refer to studies by, such as Helldén and Solomon (2004) that refer to the importance of early learning scientific conceptions. Their conclusions indicated are in accordance with *IPCC* and *NASA*, since the trends of their categorized conclusions show that young pupils are conscious about natural as well as anthropogenic connections and interrelations.

It is obvious that people in future need both deeper subject knowledge and opportunities for interdisciplinary and integrated learning, since learning for sustainability has to be based on how the technology and lifestyle in the modern society will influence the lithosphere, hydrosphere, atmosphere and consequently all life on Earth. The model of the Earth and the spheres illustrates clearly how the natural spheres are connected and dependent on man, technology and society both in detail as well as holistically, including changes over time. It may be of importance in what way we will look at science education as a whole in the future.

These alternatives need to be offered to pupils in schools. Also, this study indicates the importance of developing environmental concepts in pupils' early years. The quality of the content found in the dialogues seems to indicate a good standard; however, the question on the teacher's ability to support every single pupil's individual development still remains.

The most important implication of this study is how environmental education of this kind stimulates learning for sustainable development and how further research will impact the worldwide review of school curricula. The teacher stimulates the learning by expending on the concepts relevant to the children's growing interest (Bruner, 1996). This creates discussions with the pupils as well as between them. Some of the questions are taken home for further discussions with their parents. In addition, they sometimes have to solve problems by contacting somebody in the community or by searching through newspapers. The study can be summarized as a new way to look at environmental issues and to avoid marginalizing them in environmental learning and teaching by using *Earth System Science, ESS,* and *Earth System Science Education, ESSE*.

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