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9 English Summary: Symphony of the spheres in change? Learning in environment for sustainable development in primary school with a scientific and longitudinal approach

9.1 Introduction

This study focuses on how young children in primary school develop concepts in their science learning. The described study takes place in a Swedish primary school with 28 pupils who were nine years old when the longitudinal study started. Data collection started in 2003 and finished in 2006. The investigation concentrates on the pupils' study in science, which is led by a science teacher who organized and planned all the lessons. In the Swedish school, *Environment* and *Sustainable development* are not classified as specific subjects, but instead listed as two obligatory perspectives in school education. Due to these circumstances you have to take into consideration social as well as economic and technical aspects. As a consequence, every established subject as e.g. science is expected to deal with environmental issues and sustainable development in the Swedish education school system.

Traditionally, educational research in environmental issues are concentrated on how different parts of environmental learning and learning for sustainable development can be transformed into selected projects in established research and school subjects. The substantial content in environmental education and learning for sustainable development run the risk to be marginalized and replaced by fragments from different subjects and didactics (Gough, A., 2002; Huckle & Sterling, 2001). Until now, environmental research, education and learning have often been concentrated on environmental problems and not on how to avoid them.

A lot of investigations deal with understanding the evolution of environmental concepts and conceptions mainly related to ecology and biology. But there are also some studies focusing on models in environmental education and learning (Hart & Nolan, 1999; Östman, 2003). Attitudes and engagement in the environment and sustainable development among teachers and pupils are also important research areas (Loughland et al., 2002). Another field includes curricula (Bhaskar, 2003; Hermele, 2006; Wickenberg, 1999; Östman, 2003).

Rickinson (2001) points out that most surveys concerning *environmental science* are short-term studies performed with students in school. Hence, there is a need for long-term studies. Gunstone and White (2000) also argue about the need of long-term studies and claim that longitudinal studies will significantly contribute to the understanding of what factors influence development of concepts and conceptions. In view of these arguments, in this thesis I consequently investigate the formation of concepts in a longitudinal perspective.

9.1.1 Aim and research question

The purpose of this study is to analyse how pupils' formation of concepts in their science learning are related to the *Earth System Science* (ESS), as a scientific framework (Andersson, 2001; Bretherton's Diagram, 2006; Johnson et al., 2000).

The research question in this longitudinal study is formulated as follows:

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

In this study, I will describe and analyse both the results of the group as well as the individual results. The development of the pupils' formations of concepts related to the different spheres will be analysed in a longitudinal study by observing a group of 28 pupils in video and questionnaires and also ten of them in semi-structured interviews over a three-years period.

9.2 Background

The scientific approach in this thesis is connected to the international request from Johannesburg 2002, *The World Summit on Sustainable Development* (WSSD), and especially the part concerning, *The International Council of Scientific Unions* (ICSU), in Ubuntu. ICSU pointed out the importance for researchers and teachers to use science and technology to better face the challenge of sustainable development (Bhaskar, 2003). UNESCO has also declared the period of 2005 - 2014 as *The United Nations Decade of Education for Sustainable Development* (UNESCO, 2005). Environment is expressed as an obligatory subject for survival, which means that learning in environment for sustainable development cannot be satisfied without specific didactics (Gough, A., 2002). 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, this study is related to international trends.

9.2.1 Theoretical framework

Human and the environment as background

The modern worldwide need for environmental protection is a result of the rapid population growth in the past century. The need for global environmental protection has been the topic of three recent environmental summits, in 1972, 1992, 2002. Even though mankind's relation to nature has a long history, modern day environmental problems have become increasingly obvious. At present, they are leading to awareness, changing attitudes and a stronger driving force towards sustainable development.

The scientific history as we know it is from the beginning in some way related to the philosophers in Greece, e.g. Plato, 427- 347 B.C. and Aristotle, 382 – 322 B.C., who tried to analyse the rules in nature and our relation to them. Plato briefly described humans as divided into body and soul or spirit, which is almost the same as it is written in the Bible. In some way, the old natural philosophers in Greece had another opinion than we have learned from Genesis. In the first book of the Bible it is for example stated that the man may dominate over the fish in the seas, the birds in the sky and all animals on Earth, and that he was to conquer the Earth.

With this in mind, we can follow the thoughts of the world as Descartes interpreted them (1596 – 1650, A.D.) as dualistic, in which man consists of a living body on Earth and a spirit living in eternity. Descartes found a form of rationalistic philosophy. During the same period Galileo (1564 – 1642 A.D.) and Kepler (1571 – 1630 A.D.) introduced empirical methods in sciences, stimulating our abilities to discover the rules of nature. In the nineteenth century, Darwin presented his ideas in the books *On the origin of species* and *The descent of man*, which gave man a place among others in nature. But the question is now, as before, how we should act. We have a unique position as a thinking organism on Earth, named by Linneus as *Homo sapiens sapiens* (Uddenberg, 2005).

A lot of people find a relation to nature and the environment from ecological or biological knowledge (Haeckel, 1882; Odum, E. P., 1971; Tansley, 1923, 1939). Others are influenced by the industrial and technological progress during the last centuries and have also a technological perspective on environment and nature (Hill, 1998, 1999; Huckle & Sterling, 2001; McNeill, 2000, 2003; von Wright, 2000). As a result of the economic progress in the short term we have exploited the environment in an egocentric way for this generation only.

We must see the struggle for sustainable development today with that in mind (Brundtlandkommissionen, 1987; UNESCO, 2005). Thinking as human beings we must take responsibility for the exploitation of the environment. In this case the anthroposophic and ecosophic perspective will be mentioned as important supporting the work towards sustainable development (Naess, 1981; Scharff & Dusek, 2003). We have to be aware of the human impact in all ecological systems, in detail as well as in its entirety, due to the increasing population and change of lifestyle. As a consequence research and education in environmental issues have gradually changed focus from *ecological science* to *environmental science* (Odum, E.P. & Odum, H. T., 1971; Odum, E.P., 1993).

Man has individual views and relations to nature and the environment. Hence, it is in this study important to give a short background on how for instance religion and philosophy may influence the relation between man and nature. How we look upon man's position on Earth and the relation between man and nature may influence learning in environment. Among others, I will mention Alerby (1998) and Loughland et al. (2002), who argue for a radical change in order to increase and widen the youngster's environmental understanding. I believe that there are many people who are aware of the ancient dilemmas, man's position on Earth and the role that he may play. These dilemmas are also the ontological starting points in this study.

9.2.2 Learning in science and environment

Science education is an important argument maintaining science education in school (Sjøberg, 2005; Östman, 1995). During a long time the scientists have been the heroes of the society in the western world, but due to upcoming environmental problems and other questions about technological proceedings, science has lost attraction in many countries. During the last centuries, however, *environmental science* has developed as an interdisciplinary subject in order to balance science and technology in the industrialised society (Miller, 2002; Sörlin & Öckerman, 2002). The importance of *science* and *environmental science* can be attractive to study for young people in the future (SOU, 2004:104; Åbo Akademi, 2006). Of specific interest is the evolution of modern ecological engineering and design in order to make technology adapted to nature in different ways (Bartha, 1984; Hill, 1998, 1999). *Ecological engineering* is used in many ways e.g. cleaning of contaminated water, soil and air.

Ecological design stands for new methods to create products and technical systems to avoid environmental problems today and in the future.

There are some specific differences between learning in science and learning in environment. In traditional subjects, e.g. physics and chemistry as well as mathematics, you mainly start by learning details, but learning in environment also needs a holistic approach and system thinking from the beginning (Sjøberg, 2005; Wood-Robinson, 1995). The relation between details and entirety is also a subject of philosophic thinking (Wittgenstein, 1992; von Wright, 2000). If you analyse the details and the entirety at the same time, you may find the functions and the interactions between all components (Alerby, 1998; Carlsson, 1999; Ekborg, 2002; Ingelstam, 2004).

9.2.3 Environmental didactics in different contexts

Lindahl (2003) finds in her study how pupils' understanding increase their motivation to learn. In the Swedish National Agency for Education report, *Lusten att lära – med fokus på matematik*, some situations are described that create a stronger motivation for learning. Children, youngsters and adults were asked to write down opportunities when they were involved in motivated learning. Pupils of different ages preferred practical and esthetical subjects, where both body and soul were involved in their learning. In primary school, many pupils feel joy and a pleasure to learn. The days comprise play and thematic work as well as varying methods and textbooks (Skolverket, 2003). In this thesis, the research about pupils' formation of concepts related to the Earth's natural spheres and the technosphere are investigated during their science lessons over time, from year 2003 to year 2006.

This research takes place in a class in primary school, where the pupils and their teacher during the science lessons naturally meet at different arenas. The physical places where learning takes place are in the classroom, in an outdoor education centre and in the nature. They work with two different projects from the NTA. It is a project based on science and technology for children supported by the *Royal Swedish Academy of Science and Technology*. *Play and learning* are integrated in the physical learning contexts (Ingenjörsvetenskapsakademien, 2003a, 2003b). 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 will not reveal the answers (Molander, 1996). Metacognitive dialogues are used above all in research dealing with children's ability to understand others' perspectives, *Theory of mind* (Astington, 1998). In the outdoor education centre, learning with both body and soul is emphasised (Cornell, 1994, 1998; Lingelbach & Purcell, 2000). *Play and learning* in this study are integrated in all physical contexts. In a wider perspective, non-physical contexts are integrated in the physical ones (Carlgren, 1999; Davidsson, 1999). Consequently, the themes of NTA are also integrated in the physical contexts.

9.2.4 Formation and development of environmental concepts

As in other interdisciplinary subjects, it is from the beginning difficult to find the genuine environmental concepts and relations between concepts valid in science or usable in learning for a sustainable development. In comments to the curriculum Lpo 94 concerning science, the knowledge in science as such is pronounced but also other values, e.g. the orientation in

environmental questions (Skolverket, 2000a, 2000b). In science, concepts such as *photosynthesis; respiration; evaporation; food chain; energy; matter; atom; molecule* and *chemical reactions* are used to communicate (Andersson, 2001; Eskilsson, 2001). Some concepts in science are also used in environmental learning for instance *photosynthesis; respiration; energy* and *matter* but also terms such as *decomposition; solar cell; the increasing greenhouse effect; food chain; waterpower; noise* and *welfare* are used as more specific environmental concepts and the relations between them (Areskoug, 2005; Helldén, 1995; Ingelstam, 2004; Paprotna, 1998; Skamp et al., 2004; Skolverket, 2004a; Österlind, 2005). Gradually some concepts and conceptions from more traditional research and school subjects e.g. science, technology, civics and other subjects, will become more familiar to environmental research and learning in environment and sustainable development (Hart & Nolan, 1999; Rickinson, 2001; Östman, 2003).

The aim of my study is to catch the pupils' free flow of words in their science learning. Both shorter and longer words and expressions have been selected from the videotaped sequences, without me setting the frames, during the pupils' science lessons. The study also comprises discussions on how the pupils develop those concepts in the long run and how they are related to the Earth's natural spheres and the technosphere as well as the open interactions in and between them. A concept obtains its meaning depending on which context it will be used in (Ausubel, 1968; Bruner, 1996; Vygotsky, 1986). Bruner, for instance, described *cloud* as a concept with different meanings, e.g. a cloud on the sky in meteorology or a concept in psychology to analyse a mental situation.

The pupils can use a common concept, for instance *decomposition*, and then gradually find out the casual relation to the lithosphere, hydrosphere, atmosphere and biosphere. A solar cell is another concept with its origin in a technological construction made by man to generate energy. The technosphere will give more or less impact on the natural spheres. The interactions between the lithosphere, the atmosphere, the hydrosphere and the biosphere will depend on how man will change lifestyle or technological products in different ways. When the pupils talk about the changing climate, there are interactions, especially between the geosphere, the atmosphere and the hydrosphere, which is measured as what we call the normal greenhouse effect. The increased or intensified greenhouse effect is due to that man and technology in our industrialised society influences the natural spheres in different ways. Analysis of the interactions and what depends on man and technology, is more complicated than pure meteorological or mathematical problems. But even young children develop different concepts and can see relations between concepts concerning these questions (Skamp et al., 2004).

The pupils' formation of concepts, and relations between concepts as words and expressions, is free and created in dialogues or in different experiences during playing and learning stimulated in the different contexts. In order to spatially visualise where the concepts are located I use the model of the *Earth System Science* (ESS), for the analysis. It comprises the different natural spheres and the technosphere. *Sphere* as a concept is used in science since the Greece natural philosophers tried to answer the relation between soil, water, air, fire and what those elements mean to man more than two thousand years ago.

9.2.5 Environment and sustainable development in research and education

Linguistically, the *environment* developed from the Latin words *medius locus*, which means "in the middle". In French *environment* is called *milieu* and in Swedish *miljö*, which is a

position in the middle. The original meaning is in the middle but a transition, which is difficult to explain, has happened when the word *environment* appeared in English and *Umwelt* in German. It is a transition from “in the middle” to the “surroundings”, that is to say everything close to us and around us.

When our environment changed more rapidly because of pollution in air, water and ground during the first period of industrialisation, a new interdisciplinary subject dealing with smoke and water-pollution as a health problem in factories and cities appeared in our part of the world (Sörlin & Öckerman, 2002). In the beginning, environment was identical to ecology. Linnaeus is often named as the first ecologist, when he wrote about the self renewing and self cleansing nature 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 the society was in balance with nature.

Beginning with the book *Silent spring* written by Rachel Carson, a period that concentrated on environmental problems started (Carson, 1963). Still today, research and education are primarily dealing with environmental problems rather than the questions about how to avoid them and create a sustainable development. Due to the increasing population and changing lifestyle, the balance in nature is more and more questioned, and there is a rising concern on how the impact of the society could potentially change the natural ecosystems in the long run.

The environmental problems gave incitements to a new UN Commission, led by the former Prime minister Gro Harlem Brundtland in Norway, which in 1978 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 also include a sustainable economy, technology and social welfare at the same time as wild life 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, 2002, (WSSD). The Brundtland commission and the world summits in 1992 and 2002 on environment have influenced the research and education in environment for a sustainable development to also include the society and technology.

The global warming and the increasing greenhouse effect are subjects of discussions every day in the media. There is no doubt that the increasing greenhouse effect does exist depending on man. Two thousand five hundred of the world’s foremost researchers in the field maintain this unanimously in the report of *The Intergovernmental Panel on Climate Change* (IPCC) presented in Paris in February 2007 (IPCC, 2007).

Consequently, one of the purposes of my research is to include the society as well as the natural ecosystems. In my thesis I have studied the pupils’ words and expressions according to the transformation of energy and matter in the natural ecosystems as well as in the society.

9.2.6 Learning theories

For the theoretical framework I have for instance studied learning theories by Piaget (1964, 1970), Bruner (1960, 1996) and Vygotsky (1986) as well as Ausubel (1968). The framework for learning in this empirical study contains both pupils' individual development and learning in a social context (Alexander, 2006; Anderson et al., 2000; Piaget 1932/1960; Vygotsky, 2001). The pupils' formation of concepts takes place in e.g. dialogues between the pupils and also between the teacher and the pupils. According to Piaget (1975) learning is stimulated first and foremost through cognitive conflicts appearing in the dialogues between pupils. It is in the communication with others that pupils become aware that there are other positions than their own. A pupil talking to another pupil must take the other pupils' perspective and if they disagree they meet a conflict which is social as well as cognitive. Piaget meant that cognitive conflicts become a way for the pupil to reconstruct his/her old ideas and construct them in a way, which will create a better feedback. Piaget emphasised that children achieve social as well as cognitive advantages through dialogues. These thoughts do well agree with Vygotsky's ideas about the *zone of proximal development*, *ZPD*. In accordance to Bruner (1960, 1996) one must understand concepts and structure as well as connection with real life. He observes education at an early stage 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 a similar way, as the pupils will meet them in every day living and in the future (Bruner, 1996). Their experience ought to be transferred to as many situations as possible. Vygotsky (1986) has a socio-cultural perspective postulating learning as discursive. Language is important in order to create an arena for formulating and solving problems. It gives possibilities to communicate and examine knowledge. Language is the basis for discussions and evolution of concepts and understanding (Vygotsky, 2001; Wittgenstein, 1992). Aikenhead's (1996) and Jenkin's (1996) results are important to mention according to future development of curricula. Aikenhead discusses, among other things, what science and technology are, and also how society influences science and technology. Jenkins describes how scientific literacy commonly implies an appreciation of nature and the general limitations of science, coupled with some understanding of some important scientific ideas.

I have been influenced by the conversation in the classroom according to the classical dialogue of Socrates as well as the importance of communication and language analysed by 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, which is a critical dialogue (Alexander, 2006). He also pronounces the discussions and argumentations in science and environmental education as well as meaning almost like Ausubel (Ausubel, 1968). Finally Dewey inspired me in the research when he strongly pronounced participation and shared experience and interests important in the classroom as well as in a 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 et al., 1991; van Driel & Verloop, 1999). In this case, I have chosen the Earth and the spheres as a model for the 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 (Persson & Musidłowska-Persson, 2007). The Earth's System can be used as a concept map known all over the world.

9.2.7 Earth System Science as scientific background

Learning in environmental issues, often begins with the first two laws of thermodynamics to explain that nothing will disappear and everything is spread (Tiwari, 2003). In any process the total energy of the universe remains constant and energy systems have a tendency to increase their entropy. But in this project I will widen the perspective. Hence, in order to study the environment as a whole as well as in detail I have chosen the *Earth System Science* views of the Earth. The Earth System approach has become widely accepted as a framework from which to pose disciplinary and interdisciplinary questions in relationship to mankind (ESS, 2006; Johnson et al., 2000; Skinner & Porter, 1999).

Fundamental to the approach is the need to emphasize relevant interactions between environmental processes that extend over spatial scales from microns to the size of the planet. It involves more or less complex processes in the geosphere, atmosphere, hydrosphere, biosphere and technosphere. It is a worldwide research programme concerning global change in a broad meaning for sustainable development (ESSE, 2006b; Young et al., 2006). Within the concept of the Earth as a complex and dynamic entirety involving the interacting spheres for land, air, water and life, there is no process or phenomenon that occurs in complete isolation from other elements of the system. A related research project is found in Sweden called *The International Geosphere–Biosphere Programme – A Study of Global Change, IGBP* (IGBP, 2006b). In didactics, the system, similar to *Earth System Science*, is also used by others e.g. Andersson (Andersson, 2001; Andersson et al., 1999). Andersson (2001) emphasis the relevance of the teaching content associated to the different spheres.

In the present study, I will analyse how pupils' words and expressions are related to the different spheres using ideas from the scientific framework from e.g. Andersson et al. (1999) and Johnson et al. (2000).

9.3 Methodology

9.3.1 Methods and samples

I began the longitudinal study in a 3rd form of primary school, with 29 children, in a city in southern Sweden, where the teachers work with projects in science and technology called the Swedish NTA-project to stimulate the interest and participation in environmental education. The children worked with different projects, outdoor education and excursions. Play and games also took a great place in the pupils' science learning (Persson, 2006a). The longitudinal study took place from November 2003 to May 2006 and interviews were made in November 2003, May 2004, May 2005 and in May 2006.

9.3.1.2 Design

The data was collected with the same procedure for three years, six semesters. One pupil of the 29 moved from the city. With this in mind I present the results of 28 pupils from year 2003 to 2006. It started with videotaped science lessons and questionnaires to all of the pupils in the class and ended every semester with semi-structured interviews with ten of the pupils. Two times *stimulated recall* was carried out. 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 also been taken into consideration in the study. Presentation of the data collection chronologically is as follows. I have also collected parts of the pupils' notes and drawings.

Autumn 2003

The pupils got a questionnaire before the project *Changes*, which belongs to the Swedish NTA-project, started. Then I interviewed ten of the pupils. They were selected after I had looked at the answered questionnaires according to variation and a gender perspective. I started the videotaping at the same time the questionnaires began. Each science lesson in the class was about 120 minutes.

Spring 2004

I videotaped five of the science lessons in spring year 2004. In the end of every semester I repeated the procedure with semi-structured interviews with the same ten pupils after all 28 pupils had answered the questionnaires. The questions in the questionnaires and the questions for the interviews are presented in chapter 9.5. The videotaped sequences were carried out in the classroom and in the outdoor education centre. Both the NTA-projects and play are integrated in all learning. I looked at the videotaped sequences, wrote down what was said and chose a couple of sequences for *stimulated recall* with the science teacher. The interviews with the science teacher took place at the teacher's working place.

Autumn 2004

I videotaped the pupils during their science lessons five more times. The pupils worked with a Swedish NTA-project about electricity, in Swedish called *Kretsar kring*, for two of the videotaped opportunities. The pupils were at the beach two times of the videotaped lessons and one science lesson was at the outdoor education centre. I looked at the videotaped sequences, wrote down what was said and chose a couple of sequences for *stimulated recall* with the science teacher. The interviews with the science teacher took place at the teacher's working place.

Spring 2005

All the 28 pupils answered the questionnaires which were similar to the other ones and the same ten pupils were again interviewed in the end of the semester.

Autumn 2005

The data collection continued with videotaped sequences. The pupils' tasks were e.g. to clean contaminated water and to build aqueducts as the Greeks. The pupils' notes were also collected for documentation as well as their drawings and digital photos of their work. Generalization and validity were taken into consideration and therefore pupils in other Swedish cities were asked to answer the same questions as the pupils in this study.

Spring 2006

All the 28 pupils answered the questionnaires which were similar to the other ones and the same ten pupils were again interviewed in the end of the semester. The videotaping continued and the lessons were at the outdoor education centre. The content was about water in every day life and the task was formulated: *How much water will flow in the river?* Generalization and validity were also taken into consideration.

Video recording

The most important argument for using video as a method in this study is the possibilities 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 I have videotaped sequences and transformed them and the interviews to transcripts. I have chosen video recording as a method instead of structural observations, because I think you can capture the real activities without interfering with pupil interactions (Jordan & Henderson, 1995). The video recording is a method that better transforms the real world and pupils' activities.

Interviews and Questionnaires

I have continuously carried out semi-structured interviews individually with the young pupils. Interviews were chosen as a method to complete the video-taped sequences. The interviews have been semi-structured with open-ended questions according to the concepts in the video recording. During the individual interviews I showed some artefacts to the pupil, e.g. a toy car, a book with pictures illustrating photographs of landscapes. This kind of interview worked well because it opened up the talk and the conversation as the pupil related to the artefacts (Ginsburg & Opper, 1988). During a more structured interview I had run the risk of losing what's on the pupil's mind at the moment it is carried out. 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 were taken place four times, autumn 2003, spring 2004, 2005 and 2006. The interviews followed the time table for the questionnaires but were made two weeks after the pupils had answered the questionnaires. In the questionnaires the pupils had the possibility to answer spontaneous with words, sentences and drawings.

Stimulated recall

Stimulated recall is important in order to find out the reaction of the teacher during the lessons too. The method *stimulated recall* gives the teacher possibilities to comment the work (Calderhead, 1996). The teacher has to comment some videotaped sequences in the classroom and answer some questions concerning lessons and communication in the classroom and outdoors. *Stimulated recall* is also a useful method reminding the observer what a person was

thinking during a certain episode. You can look at the collected data from a different point of view and discuss how the pupils are dealing with environmental concepts in their learning.

The Socratic dialogue

It is very interesting to observe how the teacher uses a dialogue in the classroom communication with very young children reminding us of what we know about the Socratic dialogue. His philosophy is based on knowledge through common sense mediated in dialogues (Guthrie & Keith, 1999; Molander, 1996; Taylor, 1939). In the Socratic dialogue the teacher asks questions and the learner has to look for the answers and sometimes also for the questions. It is especially interesting for learning about environmental issues because there is often more than one possible answer.

The Earth System model

In order to catch details as well as a holistic perspective, the Earth system is used as a model for the analysis (Andersson, 2001; Gough, N., 2002; Kump et al., 2004; McNeill, 2000). All processes on Earth can be related to the lithosphere, hydrosphere, atmosphere and biosphere influenced by man and society. This is a model with roots in the Greek scientific history but still usable in learning for sustainable development (Helldén et al., 2005; Persson, 2005a; Skinner & Porter, 1999). During the last twenty years, *Earth System Science Education, ESSE*, has been established dealing with environmental issues (Johnson et al., 2000). The model related to the Earth's system gives also 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 which arise from knowledge that nothing disappears and everything is spread.

To explain the model of analysis for teachers and the pupils you have to transform the scientific terms to daily talk: *The soil we set our footsteps on, The water we drink, The air we breathe and The life we live using energy and material including the technosphere, which we have created.* The pupils will take part in nature and society in this way dealing with environmental issues. Most important in the study is how young children are using environmental concepts to describe and understand what is happening in between the soil, the water, the air and how this will affect our lives (Persson, 2004).

The aim of the study is to generate knowledge of how pupils in primary school (aged 9-11) in group as well as in individual level develop concepts related to the natural spheres on Earth and to the technosphere. In purpose to analyse the pupils' development of concepts according to environmental learning and sustainable development I have chosen a model which is inspired of *the Earth System Science, the Bretherton Diagram and System Jorden* (Andersson, 2001; Andersson et al., 1999; Bretherton's Diagram, 2006; Johnson et al., 2000). The model has a scientific approach which also includes human activities on Earth. It also gives opportunity to study science and environmental issues in a holistic point of view as well as in detail (Söderqvist et al., 2004). With the model you are able to analyse the pupils' development of words, expressions and games in relation to what is happening in and in between all the spheres.

The 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 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.

9.4 Analysis

9.4.1 Content of data collection

Data collection comprised 30 hours of video recorded lessons in science, without me setting the frames. The answers from questionnaires (1176) and semi-structured interview answers (420) were compiled. Four hours interviews by the science teacher were also included in the data collection besides the documentation of notes, drawings and narratives from the pupils produced during the science lessons.

9.4.2 The process of the analysis

Since environmental learning and learning for sustainable development do not exist as independent subject in the Swedish educational system, the development of environmental concepts and conceptions used in learning for sustainable development are proportionally vague. *Environmental Science* and *Environmental Education* are young sciences and have mostly developed from analyses of different environmental problems, as identified by man, in relation to nature that has not been influenced by man.

The questionnaires and the interviews have been worked out by carefully reading the written empirical material and then transferred to word documents. The categories for the analyses are not hierarchical designed. In this study a 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 below 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 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 you find answers that express simple natural causal relations, while category B2 contains more complicated expressions that contain interactions in and between the different natural spheres.

Categories C1 and C2 contain answers including expressions that 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 hierarchical built. It has two forks, pathway B1-B2 and pathway C1- C2 (figure 9.1). It is not a linear categorisation, but the categories are integrated 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 $X_1, X_2, X_3, X_4, \dots X_n$, which can be summarised as the answers categorised as A, B1 and B2. Since human impact – or human as 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 even more 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 in change.

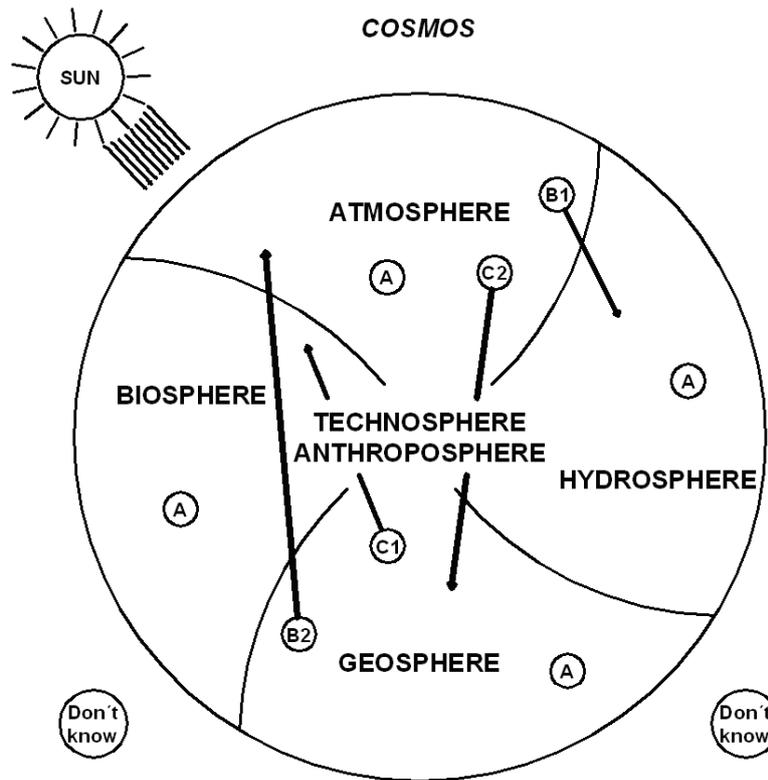


Figure 9.1. Illustration of *Earth System Science, ESS*, a simplified version after Johnson et al. (2000) with examples included. A, B1, B2, C1 and C2 are the different categories.

9.5 Results

The video-recorded sequences are important in the study because they enabled me to catch the pupils’ development of concepts as unprejudiced 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 have been added and all the questions were adapted to the young pupils’ level. The results showed that several different concepts were connected into a network, a 'concept web'.

The concepts that were found 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*
- *The increasing greenhouse effect*

The questions asked were:

- In what way is rain created?
- The teacher has pored water on the sink. What will happen if it will not be dried at once?
- What do plants and animals need for living?
- Look into the bag. This is soil taken from the compost. How can it become soil in the compost?
- What happens with the content in the toilet when you flush?
- Where does the tap-water come from?
- What happens when oil gets into the sea?
- Why do we sort waste?
- Why do we collect batteries?
- How will it become corrosion?
- What do you mean with a bus 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 that?

The pupils' answers and expressions have been categorised as described in chapter 9.4.2. 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 develop concepts on *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 pupils express their answers to be 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 their living can be classified as A with the trend category B2 and the question about the water being left on the sink as the trend B1.

There are concepts that the pupils state as quite scientific. *In what way is rain created?* and *The teacher has pored water on 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. *the increasing greenhouse effect* where also adults argue about the natural and anthropogenic causes. Concepts such as *life; the increasing greenhouse effect; batteries; pollution; non-polluting busses* and *water in every day life* comprise answers from the pupils that also are related to atoms, molecules and where physical and chemical explanations are expressed.

The formation of concepts that are analysed in this study can in some cases be identified as conceptual changes. The pupils change their answers and expressions quickly from one year to another while there are 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 for the analysis. From the material I have constructed descriptions of the group, but I also present a summarised development of two of the pupils in case studies.

9.5.1 Results from the video recording

The hydrological cycle

I will give one example of a dialogue between the teacher and the pupils which illustrates the way they express how pollution is spread in nature. What happens when oil gets into the sea is the question the teacher and her pupils are dealing with. It is interesting to notice how they follow the hydrological circle to describe the cycle of materials and energy in detail as well as a whole.

- Teacher: Yes, what do you think? Do you think it is dirty just when it evaporates from the water surface?
- Sune: Yes, a little bit. I think there will be a little bit left.
- Teacher: You think there will be a little bit of pollution when it evaporates?
- Sune: Yes.
- Teacher: Hm. I think just in the moment it will evaporate it will be mostly clean in the hydrological cycle. But the clouds will be dirty. How can it happen?
- Sune: Because the pollution goes up to the clouds.
- Teacher: How do you mean?
- Sune: Yes, the water–steam will be cloud.
- Teacher: Yes, is the water–steam polluted?
- Sune: No, but if it is pollution in it will be polluted.
- Teacher: But what happened with the water? The pollution was left at the sea bottom and what was happening with the water when the sun was shining on it?
- Sune: I think the pollution will be in some way spread.
- Teacher: Mm.
- Sune: If, as we said, gasoline was built up by molecules there would be like more molecules.

Notice how the discussion in the Socratic dialogue is formed about the hydrological cycle but also how water will be contaminated by pollution. The formation of environmental concepts also provides a micro perspective as well as a macro perspective of atoms and molecules.

- Teacher: Do you remember how many atoms that were joined together for a water molecule?
- Otto: A million.
- Teacher: For a drop of water, yes, but how many atoms were required for one water molecule? Do you remember, Bob?
- Bob: Three, I think. One of hydrogen and two of oxygen.
- Teacher: Almost.
- Bob: Or ... No it was the opposite. One of oxygen and two of the hydrogen.
- Teacher: Correct.

Teacher: Do you remember what it looked like?
 Kenny: Yes, like Mickey Mouse!
 Teacher: Yes, correct. And there would be millions of molecules like that in a drop of water. But as you said, Sune, there are molecules in gasoline too. Everything is built up by molecules.
 Sune: The pollution may reach the groundwater.
 Teacher: The pollution may reach the groundwater. How may it reach the groundwater?
 Sune: Sinking through the ground.
 Teacher: You mean, the gas will first be added to the cloud and then joining the water to the ground and to the groundwater?
 Sune: Maybe.

Notice how the discussion goes on about the hydrological cycle but also how water will be contaminated by pollution. They also discuss how water can be filtered by pores in the soil and turn polluted water into the groundwater. Gradually they ask what happens in the hydrological cycle including human impact in different stages.

Results from the questionnaires and the interviews tell more about the pupils' ideas according to the spheres (figure 9.1). Some pupils express how water will be contaminated by pollution and some of them express that new 'pure' air from exhaust pipes was formed into clouds when they get dark and heavy it starts to rain (figure 9.2).

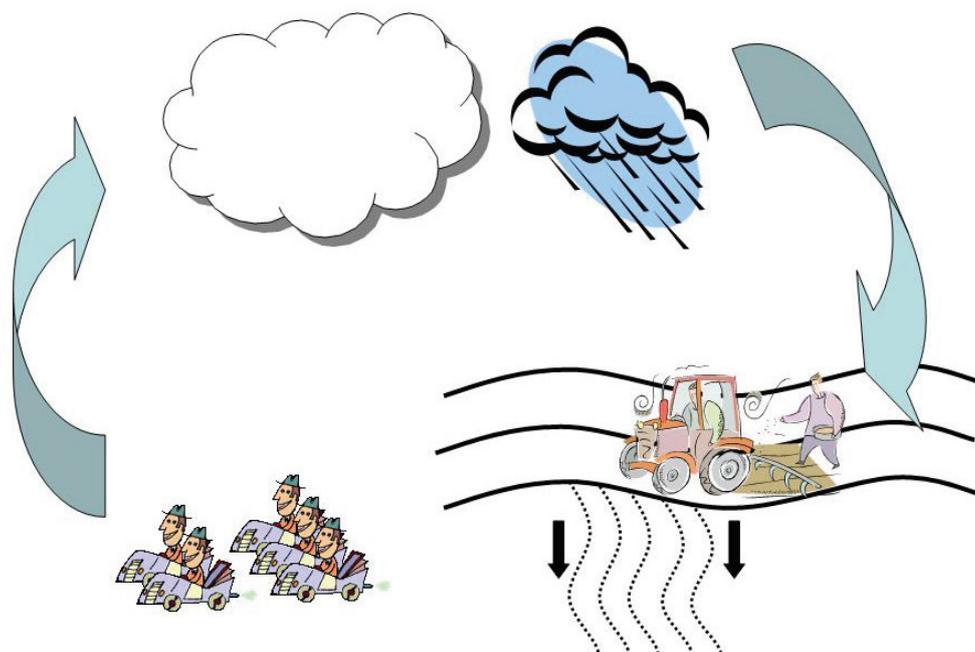


Figure 9.2. Summary of the childrens' ideas about the hydrological cycle.

The development of the formation of environmental concepts shows the transition from using everyday concepts to scientific concepts and relations e.g. the pure water cycle, but also put in relation what is happening when water is contaminated by pollution. The 'concept-web' developing in the area concerning poison is connected to the natural cycles. Many toxic substances are soluble in water which makes possibilities for the pupils starting with the concepts they already are aware of. Further more the pupils in this study will meet toxic substances that are soluble in fat. The pupils use the atmosphere, the hydrosphere, the

lithosphere and biosphere as well as the technosphere/anthroposphere in their formation of environmental concepts.

Non-polluting busses and other vehicles

In this study it is possible to observe what is happening in and between the different spheres and the young pupil's discussion. The pupils consider the exhaust from a vehicle: *How will it be spread? Will it come to the soil again?* They are talking about buildings weathering and pollution entering the groundwater after rain. According to the pupils' homework they were supposed to ask their parents about busses, traditional compared to others with alternative fuel, as hydrogen gas and bio-fuel. The following interview-transcripts appeared from Sonja's, Hans' and Bob's interviews in 2005 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.*

Sonja: The exhausts will get 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 biogas 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: Electric cars and biogas. That is what the plants are used to. Animals and plants can get sick. The exhaust is not healthy. It 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: 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.

The following is one example of a dialogue between the teacher and the pupils to illustrate that pupils can understand what happen if the amount of carbon dioxide increases in the atmosphere. This example concentrates on studying the interfaces between the technosphere, atmosphere and biosphere.

The increasing greenhouse effect

The dialogue between the teacher and the pupils, nine years old.

Teacher: Carbon dioxide is released into the air when we breathe and all the trees will assimilate the gas. Carbon dioxide also comes from the exhaust pipes of the cars. When plants decay and become soil some carbon dioxide will be released. If there is too much carbon dioxide in the air, then the carbon dioxide will influence the radiation from the sun and the Earth. The heat will not be able to escape from the Earth, which means that some radiation will stay on Earth and what will happen to the temperature then?

Bob: Very hot. It has been like that in Paris.

Teacher: Right. Very good. Maybe not very hot.

Bob: No, but it will be warmer. ...after a while. It will anyway be warmer later.

The teacher will in some way be surprised when the pupils give distinct answers and relevant examples in a continuous conversation. This is an example of the Socratic dialogue in

practice. In *stimulated recall* the teacher discusses the difficulties in environmental learning. You have to find scientific facts as well as values. The classroom talk continues and the hydrosphere and the biosphere are also involved in it.

Teacher: What happens on the Earth if it gets very warm? What happens ... Yes, what happens?
Björn: By the way. We sent out very much carbon dioxide this summer. We put gasoline on a thatch that we had pulled down and burned.
Teacher: Oh, dear.

Notice how the pupils use examples of global change, at first Paris and then when another one talked about gasoline on a thatch.

Stig: The ice on the poles will melt if it is getting warmer.
Teacher: What happens if the ice will melt at the poles? What happens?
Hans: The sea will get higher.
Teacher: What happens then with the people living near the beach?
Jenny: Flood. They have to move to another place.
Teacher: They can't live at the sea because there is too much water.
Bob: Where it is not getting any more water, there it will be dry.
Teacher: That's right. Because it gets too warm you mean? If we continue letting out carbon dioxide and other gases then the ice at the poles will melt.
Bob: Then there is this greenhouse effect.
Teacher: Good. How does it feel like visiting a greenhouse inside?
Bob: Hot, warm and muggy.

Finally one pupil is the first in the dialogue using the concept, greenhouse effect. The teacher is consequently using an inquiry method almost like Socrates, in which one question leads to another until they are familiar with the concept and the environmental applications. The examples from everyday life can often be a real adventure stimulating the children's hearts, brains as well as hands.

The pupils have met the concept carbon dioxide in the recorded lessons about photosynthesis. How the green plants need carbon dioxide, which humans and animals exhale. The pupils discuss if they can find carbon dioxide in other places. They have noticed it in soda and champagne, which can give a real explosion when opening the bottle. But they have also noticed the small holes, when baking cakes, from which the gas transpires. The pupils received homework to discuss with their parents what it means for a city when there will be busses with alternative fuels as e.g. hydrogen gas or bio-fuel. This is an example of scaffolding.

Since the project is a longitudinal study it includes also the aim to investigate the pupils' development concerning using environmental contexts from the first interviews and lessons in 2003 to the next one in 2004, 2005 and even in 2006. *The increasing greenhouse effect* as a concept is turning up for most of the pupils in 2005 and the answers are related to non-polluting busses and other vehicles.

The questions were: *Have you heard about the increasing greenhouse effect? What is it then?*

Bob (2004): Isn't it something about that if it is too much greenhouse effect there will be warm or something. Was it not anything like that? And it was so in Paris not long ago. It was too hot. It was more than 40 degrees over zero. Maybe there were too many exhausts.

Bob (2005): 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.

This is of course only one example of higher temperature in one summer. But concerning the *increasing greenhouse effect* the weather conditions during long time has to be taken into consideration.

Bob (2006): 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.

It is noticeable that Bob is more determined in his answers from one year to another, even though he mixes the increasing greenhouse effect with hole in the ozone layer. Maybe this is a result illustrating learning for sustainability. Sonja's and Hans answers about *the increasing green house effect* are caught as follows.

Hans (2005): I have heard about it but I don't know what it is.

Hans (2006): Anything that is not good for the environment.

Sonja (2005): I don't know.

Sonja (2006): 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 when we are using too much carbon dioxide and other gases. It will destroy the ozone layer.

The children argue about how we can avoid environmental problems. Sonja follows the processes from polluting cars into the technosphere influencing the atmosphere and biosphere, which might demand new technology. They also suggest innovations according to ecological engineering and argue for new technology as a key changing their lifestyle (Hill, 1998, 1999). The interviews with some of the pupils also show their views of the relation between the hole in the ozone layer and the increasing greenhouse effect. At this age children can not distinguish long wave thermal radiation from short wave radiation from space.

The science teacher in Stimulated recall

The teacher points out difficulties in environmental learning, but from time to time takes examples from everyday life. She is consequently using an inquiry method. She is aware of the spiral-principle to Bruner (1960, 1996), but hardly familiar with Socratic dialogue. Accordingly, the science teacher discusses the problem in environmental teaching concerning the difficulty to find only one right answer to environmental issues. There are, she says, environmental concepts and facts but also space for values. The teacher is also aware of the possibilities of using every day concepts and transforming them into science. The teacher changes in her teaching spontaneously from a holistic perspective to details and vice versa, characterizing the Earth's model. Her comment after looking at videosequences supporting this behaviour is:

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

9.5.2 Case studies

I will present the summaries of two of the ten case studies, Mary's and Sune's. With *theme* I mean the pupils words and expressions that return in their answers over time.

Mary

Some of Mary's answers are characteristic for a *conceptual change*. The question about the increasing greenhouse effect is first classified as 'I don't know' in year 2003. The following years (2004-2006) the answers are classified as C2. Similarly to several of the other pupils' answers in the class, Mary's answers to why and how waste should be recycled are categorized as C1, while the answers to why batteries are collected are classified as category A.

One theme that appears in several of Mary's answers is her reasoning about the way things are spread in nature, i.e. she is applying the first two laws of thermodynamics. The concept of *pollution* changes in Mary's case over time from category C1, to B1 and finally to B2 in 2005 and 2006. There is obviously a conflict between pathway B and pathway C. Mary finds several connections between different concepts, e.g. *non-polluting busses* and *the increasing greenhouse effect*. Health is another theme that returns in her expressed answers over time.

Sune

Sune develops parallel concepts to several of the questions he is asked about. His answers indicate a *conceptual change* as well as *conceptual capture*. Significant for Sune is his theme containing technical solutions for a sustainable development. Similarly to Mary, he makes connections between different concepts. Sune points out toxic substances and pollution from for instance batteries and vehicles, spread in the water we drink and into the ground. He also mentions reasonable scenarios in the future.

Generally the pupils' answers agree with the answers from Mary and Sune. There is obviously a conflict between pathway B and pathway C according to concepts such as *pollution; corrosion; collecting batteries; greenhouse and the increasing greenhouse effect*. Examples exemplifying the first two laws of thermodynamics are common in their answers as well as the health perspective. The majority of the pupils also express that pollution from vessels kill fish and birds in first place, but not humans. Several of the pupils also mention technical solutions in order to avoid environmental problems in the future saving resources from nature, e.g. the forests, sand and minerals on Earth.

9.6 What is new in the study?

In this thesis a modified version of the model *ESS* has been used. It is derived from the *Earth System Science* and the *International Max Planck Research School on Earth System Modelling*. Equivalent to, the *Earth System Science*, are in Sweden *System Jorden* (Andersson, 2001) and *Tillståndet i världen* (Andersson et al., 1999). My model is also inspired by Bretherton's diagram (Bretherton's Diagram, 2006; Johnson et al., 2000). In the Earth System model, the instrument for the analysis, linear as well as integrated categorisations of the pupils' answers occur. The study contains unique empirical data gathered over time including transcripts from videotaped science lessons, interviews and the pupils' expressions and drawings in their questionnaires. To the best of my knowledge I am not aware of any similar study of this kind.

The *Socratic dialogue* and *Play and learning* as methods in science learning are some of the novelties of my study as well. These two methods are very useful in environmental learning and learning for sustainable development since there are often more than one correct answer and all the time new questions, e.g. from an existential perspective appear.

9.6.1 Which new questions are posed?

With examples from everyday life and other facts it is possible to give signals to the pupils about the environment (Österlind, 2005). Some pupils can see the connection between the increasing green house effect and pollution from cars. Others can see relations between increasing temperature and melting poles. They see problems for people to live in places with coastal areas when e.g. the sea will get higher. The pupils have in the lessons heard about the increasing greenhouse effect. They have heard about photosynthesis which needs carbon dioxide and how it feels to go into a greenhouse. They can argue about possibilities to change different habits in the technosphere in different ways, which reduce disturbances in the lithosphere, atmosphere and hydrosphere, and favourably affect the biosphere and human life. As an example the pupils discuss vehicles with less pollution. They can find out about possibilities to use rape oil, electricity and biogas instead of gasoline, in order to reduce pollution and carbon dioxide (Alerby, 1998, 2000; Hill, 1998, 1999). They start using scientific and technological concepts and try to see environmental applications and understand environmental concepts and conceptions (Skamp et al., 2004).

In the Socratic dialogue it is possible to find more than one correct answer to the question. In my research the pupils use concepts and environmental relations in the dialogues with the teacher as we think Socrates did, and they discuss if gasoline leaves the water surface at the same time as the water-steam or not. They discuss what happens in the lithosphere, in the hydrosphere and the atmosphere and how it will influence our lives. Of interest is what happens in and between the different spheres in detail e.g. on the atom and molecule level as well as the holistic level (Gough, N., 2002). Most interesting is how very young children can discuss complicated environmental issues and develop concepts concerning transformation of materials and energy in nature and society. The teacher stimulates the communication in the classroom (Alexander, 2006; Molander, 1996). She also gives structure in learning and goes ahead step by step due to the children's ability (Bruner, 1996). Environmental learning must almost always deal with details as well as generalities. It seems to be a successful starting point.

According to Bliss (1996) students also help each other to reach individual higher levels of communication between each other and with the teacher which results in meaningful learning (Mortimor & Scott, 2003). In this study the pupils meet learning in the classroom and in the outdoor education centre as well as in different NTA-projects and play activities. One interesting aspect is play as a didactic tool in the pupils' science learning. In this study, it is not obvious that the play activity does contribute to any deeper developing of concepts related to the natural spheres and the technosphere/anthroposphere in their science learning. Although, with the metacognitive dialogue before and after the play activity the pupils' views are questioned by the teacher and the other pupils. *Conceptual conflicts* and development then appear. Here the theoretical framework according to e.g. Piaget and Vygotsky is worth to mention.

For further research it would be interesting to investigate some critical points when the play activities are taken place. Even the teachers' different ways to value play in relation to the

Swedish curriculum Lpfö 98 and Lpo 94 would be of great interest to study (Skolverket, 2000a, 2000b). The metacognitive phase of the pupils' learning, according to pathways B1, B2 and C1, C2, is also important to further analyse. For additional research it 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.

Traditionally, learning about environmental issues is realised as different projects in cooperation between separate subjects like physics, chemistry, biology, and civics (Andersson, 2001; Sjøberg, 2005). In such case the environment and different processes in nature and society often will be limited to didactics familiar to the different subjects (Gough, A., 2002). The Earth System model using the Earth's spheres as a model can be valuable even for older pupils and in the teacher's methodology (Andersson, 2001; Gough, N., 2002). Probably the model then have to be modified at the analysis of the answers from older pupils. Maybe categorisations like B1, B2, B3, B4 and B5 as well as C1, C2, C3, C4 and C5 will appear.

The results in this study also demonstrate the goals aimed at in the Swedish curriculum, concerning learning in environment and learning for sustainable development (Skolverket, 2000a). When teaching the obligatory perspectives environment and sustainable development one has to accept the differences between learning science with scientifically already established concepts versus learning in environment for sustainable development with environmental concepts still in a state of development. One crucial point is the need for establishing a common language for the central perspectives as well as the traditional scientific subjects. A new knowledge of culture is developing. Sjøberg (2005) claims that science education has lost the concrete examples in nature. It is important in science teaching and learning to show how details and entirety do interact. Andersson (2003) means that it is far from all pupils that can see connections between *solar radiation*, *precipitation* and *lightning at home*. There are in the instrument for the analysis in this study possibilities to observe details including interactions in the natural systems as well as technical systems in society. Integration of environmental questions in different school subjects has implied a marginalization where the pupils rather have learned *about* the environment than *in* the environment. Söderqvist et al. (2004) also include mankind in their work building economical and ecological models to understand the whole. Grosslight et al. (2000) and van Driel & Verloop (1999) claim that there must be certain demands on models in science learning. The need for further training of teachers using models in their teaching and also development of different models in teaching and learning are welcome too. The scientific and longitudinal approach in the study is worth following up to see what will happen when using this model for older pupils. I think that the progress of learning in environmental issues for sustainable development has to influence different curricula in the future.

9.6.2 Sum up of the main results

I will present some important findings worth paying attention to:

- 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 busses; waste including batteries; pollution; corrosion; greenhouse and the increasing greenhouse effect*, also belong to the

- 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 with the method is the opportunities for the pupils to take part in logical reasoning where the dialogues poses new and important questions. This is imperative in environmental education and learning, since there is often more than one correct answer.
- Another finding in the study is how different methods, e.g. *Play and learning*, support environmental learning and learning for sustainable development during the science lessons.
- The longitudinal approach resulted in important findings regarding the changes in the pupils' answers over time. The pupils develop complicated 'concept webs'.
- The empirical study indicates the pupils' ability talking about solutions in terms of *ecological design* and *ecological engineering*. They also express in what way it can be possible to save resources. Environmental learning must not mean learning about environmental problems.
- The quality of the instrument for the analysis fulfils the request for investigation, a causal as well as linear and integrated learning.
- The symphony of the spheres in change, and processes occurring in and between the spheres are well captured in this study. In a future study, it would be interesting to perform a similar investigation among older students.
- The system for the analysis fulfils the request for generalization concerning the imitation of reality, the accuracy of data measurements and transferability.

Finally development of concepts is one research area and development of knowledge another. The first step, however, to conquer knowledge and reach the established goals stated in the curriculum is to develop concepts. In my study, there is a spectrum of different ways where the pupils' develop different concepts, e.g. *the hydrological cycle; soil; life; corrosion; non-polluting busses and the increasing greenhouse effect*. Of course there must be a connection between the pupils' learning and their individual development. Questions to ask concerning this matter is for instance what different possibilities the teacher has in order to obtain continuity in the pupils' individual development in groups with 28-36 pupils compared to classes with 15-20 pupils.

9.7 Learning environmental science in the future?

From my point of view, *Earth System Science* is a valuable tool that will become even more useful in the future with the purpose to develop education and learning in environment and sustainable development. I believe that it is likely that traditions in environmental education and research and sustainable development will change.

9.7.1 Implications

I think learning in environment and learning for sustainable development assume understanding of the way our lifestyle influences the environment both locally and globally. All people taking an active part in schools, colleges and universities ought to incorporate these basic insights with the way our lifestyles affect our global footprints.

The interviews with some of the pupils in the class clearly show how primary school children conceptualize environmental concepts e.g. the increasing greenhouse effect because of the increasing amount of carbon dioxide. During the analysis I have also found advantages to start dealing with environmental questions according to a model from our scientific history with applications in the children's everyday life. In some way, when we talk about sustainability, we are in the same position as man has been during the past centuries. We must choose the future as well as we can. It is possible to follow what can happen in the atmosphere and our everyday life with pollution created by man. Sometimes the discussion starts with details on a micro level and continues to a holistic level using environmental conceptions (Gough, N., 2002; Huckle & Sterling, 2001; von Wright, 2000). It is a challenge for teachers, teacher students and students to apply these thoughts in other subjects taught in school. Maybe the model for the analysis in this study can be worth developing. The pupils' awareness being a part of nature or not, is perhaps also worth further investigation.

The present study can serve as a guide for the teacher education and further training concerning these questions at all levels in the Swedish School Education System. Another possibility is to develop models illustrating both macro and micro level in learning. Finally, the results show the importance and successfulness of a scientific perspective as a starting point. Facts as basic knowledge in constructing and developing attitudes and lines of action in environmental and existential questions are very important in the future (Bhaskar, 2003).

The most important implication 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 consequently uses a Socratic dialog. She stimulates the learning following up the concepts step by step due to the children's growing interest (Bruner, 1996). It will create discussions with the pupils and between them. Some questions they take home for further discussions with their parents and sometimes they have to solve problems by contacting somebody in the community or by looking in the newspapers.

In my point of view, it is also interesting how very young children can discuss complicated environmental issues and find out the needs for a 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 (Bliss, 1996; Dewey, 1916).

9.8 Concluding remarks

The target group for this study consists of teachers and researchers in science education as well as decision-makers on several levels in the society, especially in the education area. It may be necessary to reconsider and give priority to the research area environmental didactics.

Today the work for a sustainable development has been more urgent in learning and education due to more frequent environmental problems (UNESCO, 2005). It is more relevant than ever to use the metaphor about the boiling frog described as a frog, which will not jump into a

bowl with boiling water. If the temperature instead gradually increases, the frog will keep swimming around in the bowl and will not take notice of the high temperature until it is too late.

The data collection in this study has been caught in the pupils' science learning from year 2003 to year 2006 with an established Swedish curriculum. The obligatory perspectives environmental learning and learning for sustainable development are fixed parts of the curriculum too. The results of the study show that you can meet both perspectives during the science lessons and at the same time obey the curriculum. Notable is that *Play and learning* today has an important role in the Swedish curriculum and is explicitly formulated as a method the pupils ought to meet in their learning.

The fundamental in developing a new kind of culture of knowledge and interest is to introduce the language of the new area early in childrens' life. In my opinion, the culture of learning environment and learning for sustainable development has just started. The current concepts regarding *batteries*, *corrosion* and *non-polluting busses* are of equal value to concepts used in the culture of learning computer science, e.g. *cd-rome*, *RAM*, *bytes*, *cpu*, *XP* etc. It should be valuable to focus on learning *in* environment instead of *about* environmental issues, since you are a part of nature all the time and you cannot chose to take a step back when you feel that it is more comfortable for man.

I suggest that we have to start with science and the environmental perspective and learning for sustainable development very early in school, since the results in this study indicates that the pupils' formation of different themes and developing of environmental concepts start in early years. Their expressions indicate concordance to *IPCC* and *NASA*, since the trends of their categorized expressions show that young pupils are conscious about natural as well as anthropogenic connections and relations.

Incitement for further research consists of the worldwide challenge that *The United Nations Decade of Education for Sustainable Development* (UNESCO, 2005) applies as well as what *The Intergovernmental Panel on Climate Change* does (IPCC, 2007). *IPCC* has distinctly established that decisions taken today about 6,5 billions of people, the entire Earth's population, affect the composition of the spheres today as well as in the future. These circumstances have to be taken into consideration in a different way in further research.

I would like to claim that the people in the future will need both deep subject knowledge and the ability for interdisciplinary and integrated learning. By this I mean that these alternatives will have to be offered to pupils in schools and this study indicates the importance of developing the pupils' formation of environmental concepts in early years. The quality of the content in the dialogues seems to indicate a good standard but the question about the teacher's possibilities supporting every single pupil's individual development still remains.

From my point of view 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 depending on man, his technology and the society in details as well as a whole and the changes over time. It can be of importance in what way we will look at science education as a whole in the future.

I hope that the outcome of my study is of worldwide interest for curricula in environmental education and learning for sustainable development. It can be summarized as a way to look at environmental issues and avoid marginalizing in environmental learning and teaching. Finally, it is interesting to find the clear connection between the ancient philosophy in Greece and the evolution of a new scientific field, *Earth System Science*, *ESS*, and *Earth System Science Education*, *ESSE*.