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Learning environmental concepts in primary school for sustainable development

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Abstract

This paper explores environmental education research in primary school. The longitudinal study started in 2003, with 29 children nine years of age, in a city in southern Sweden. The teacher works with projects in science and technology to stimulate the pupils' interest and participation in environmental education. Semi-structured interviews with the young pupils have been carried out. In order to analyse the classroom communication between the teacher and the children and also among the children, videotaped sequences from the lessons are collected, in which the Socratic dialogue is practiced. Stimulated recall as a method is also used to find out the teacher's reactions during the lessons. In order to catch environmental details as well as a holistic perspective, the Earth's system model is used in the analysis, e.g. the lithosphere, the atmosphere and the hydrosphere as well as the biosphere and the technosphere.

It was observed that the children are able to argue about possibilities to change different daily routines in different ways, which reduce disturbances to the environment. Some pupils can see the connection between *the increasing greenhouse effect* and pollution from the cars. Others can see relations between increasing temperature and melting polar caps. In stimulated recall the teacher points out possible connections in the Earth system and in environmental learning.

This material is one part of an ongoing longitudinal doctoral study and the videotaped sequences have been caught from year 2003 to 2006. The interviews with the children have been taped every spring from year 2003 to 2006.

Keywords: environmental learning, primary school, the Earth's system model, classroom communication, ecological engineering

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Introduction

This study addresses the following questions on environmental education:

How do primary school children use environmental concepts e.g. the hydrological cycle and the increasing greenhouse effect, when talking about simple environmental issues? How are the children arguing and acting for a sustainable future?

In this study simple concepts are analyzed as well as more complicated relations between concepts.

Environment and environmental learning have an interdisciplinary approach with different perspectives, e.g. economical and social. In this project we have chosen a scientific approach in order to study how young children in primary school use environmental concepts and relationships among Earth system processes and how they will influence their way of arguing and acting for sustainable development. In this respect the research follows the urgent request from the global environmental conference in Johannesburg 2002 (WSSD), and especially the part concerning The International Council of Scientific Unions (ICSU) in Ubuntu. ICSU has pointed out the importance of using science and technology by researchers and teachers facing the challenge of sustainable development (Bhaskar, 2003). UNESCO has also declared the period 2005-2014 as the United Nations Decade of Education for Sustainable Development (UNESCO, 2005).

Traditionally environmental education concerns learning *about* environmental issues as separate projects in school from time to time (Gough, A., 2002). However, by learning *about* environmental issues in different subjects, environmental education can be marginalized. In our opinion learning and education *in* environmental issues *for* sustainability will be a key question for the future (Gough, A., 2002; Gough, N., 2002; Huckle & Sterling, 2001; Tiwari, 2003; von Wright, 2000).

Learning in environmental issues often begins with the first two laws of thermodynamics to explain that nothing will disappear and everything is dissipated (Tiwari, 2003). But in this project we will go further. The Victoria Board of Studies, 2000:12, reports that in any process the total energy of the universe remains constant and energy systems have a tendency to increase their entropy.

The Earth's structure, described as Earth System Science, ESS, consists of four major categories: hydrosphere, lithosphere, atmosphere and biosphere (Young, Noone & Steffen, 2006).

> The Earth's structure may be classified into four categories: hydrosphere, lithosphere, atmosphere and biosphere. This area of study examines the processes occurring within the spheres of the Earth and the interaction that occur in and between the ecological components of each major category.
>
> (Gough, N., 2002, p. 1222)

Andersson (2001) also includes the technosphere created in society. The anthroposphere includes all human activities in society.

However, in our research the environmental perspectives are widened when the pupils use experiences from daily life and different kinds of activities in their classroom communication (Persson, 2006). Another aim is to enhance the interest in science and technology which are required in school and clarify the connection between science and technology as well as society influencing the environment (Hill, 1998, 1999; Sjøberg, 2005).

This study offers an interesting discussion about how educators can change attitudes and thinking of people, using technology, to avoid pollution in the air, water and in the ground. The pupils and their teacher discuss how to recycle and how to use ecological engineering e.g. creating non-polluting cars and other vehicles. This new scientific area is referred to as ecological design or bionik mentioned by Hill among others (Hill, 1998, 1999; Musidłowska-Persson, Alm & Emanuelsson, 2007).

Theoretical framework

Human and the environment as background

The modern worldwide need for environmental protection is a product of the rapid growth of humanity in the past century. The need for global environmental protection has been the topic of three recent environmental summits, 1972, 1992, 2002. Though humankind's relation to nature and the environment has a long history, modern day environmental problems, like dirty pearls on a string, have become increasingly obvious and are leading to changing attitudes.

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 in the Bible is for example stated that man may dominate over the fishes in the seas, the birds on the sky and all animals on Earth and he was to conquer the Earth.

A lot of people find a relation to nature and the environment from ecological or biological knowledge (Odum, 1971). Others are influenced by the industrial and technological progress during the last centuries and have also a technological perspective on environment and nature (Huckle & Sterling, 2001; McNeill, 2000, 2003; von Wright, 2000). As a result of 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 (Brundtland, 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 in supporting the work towards sustainable development (Scharff & Dusek, 2003).

Due to the increased world population and our changing lifestyle we have to be aware of the situation in the world as a whole as well as in all details.

Learning theories

For the theoretical framework we have studied learning theories by Bruner (1960, 1996) and Vygotsky (1986) as well as Aikenhead (1996) and Jenkins (1996). In accordance to Bruner (1960) 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 found a progressive development in learning, which is important in a longitudinal study. That is what we know as the spiral principle (Bruner, 1960).

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. Learning and communication depends on the practical situation, which you take part in or outside school, which we will come back to later (Devine-Wright & Fleming, 2004). Aikenheads (1996) and Jenkins (1996) results are important to mention according to future development of curriculum and the importance of social and scientific concepts. 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.

We 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; Vygotskij, 1986). The process that enables a child to solve a problem with help from an adult, scaffolding, is one part of our theoretical bases (Bliss, 1996; Bruner, 1996; Wood, Bruner & Ross, 1976; Vygotskij, 1986). We have also taken part in what is called exploratory talk, which is a critical dialogue (Alexander, 2006; Barnes & Todd, 1995; Rojas-Drummond & Mercer, 2004). Mortimer & Scott (2003) also observe the discussions and argumentations in science and environmental education as well as meaning. The classroom dialogue is only the smallest scale of a social communication besides family, community and church (Lemke, 2001). Finally, Dewey inspired us in our research when he strongly noted participation, shared experience and shared interests as important in the

classroom as well as in a democratic society (Dewey, 1916a, 1916b). The theories used also refer to the teachers' 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). In this case, we have chosen the Earth and the spheres as a model for the analysis, which even young children can understand when they stand on the ground, breath the air, drink water, use technology and reflect on how they live. The Earth's system can be used as a concept map (Novak, 1993) known over the world.

Methods and procedure

We began the longitudinal study in a 3rd form of primary school, with 29 nine year old children, in a city in southern Sweden, where the teachers work with projects in science and technology (The Swedish NTA-project)[1] 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 teaching (Persson, 2006). The longitudinal study took place from November 2003 to May 2005 and interviews were made in November 2003, May 2004 and May 2005.

Interviews

We have carried out semi-structured interviews individually with the young pupils when they started and when they finished different projects (Patton, 2002). We have chosen interviews as a method in order to function as a complement to the video-taped sequences. The interviews have been semi-structured with open questions and during the interviews the pupils had some artefacts in front of them such as a toy car, or a book with pictures illustrating photographs of landscapes (Ginsburg & Opper, 1988). This kind of interview worked well because it opened up the talk and conversation as the pupil related to the artefacts. During a more structured interview we run the risk of losing what's on the pupil's mind at the moment it is carried out.

Videorecording

In order to analyse the communications between the teacher and the children and among the children we have videotaped sequences and transformed them and the interviews to transcripts. We have chosen videorecordning as a method instead of structural observations, because we think you can capture the real activities without interfering with pupil interactions (Jordan & Henderson, 1995). We find the production of a videotape as a method that better transforms the real world and pupils' activities. We think video is better than notes and observations because one can capture the real activities without interfering with pupil interactions.

[1] A project based on science and technology for children supported by The Royal Swedish Academy of Science and Technology.

Stimulated recall

Stimulated recall is also important in order to find out the reaction of the teacher during the lessons. Stimulated recall as method gives the teacher possibilities to comment on her/his work (Calderhead, 1996). The teacher has to comment on some videotaped sequences in the classroom and answer some questions concerning lessons and communication in the classroom and outdoors. Stimulated recall is also a method useful for 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 using environmental concepts in their learning.

The Socratic dialogue

It is very interesting to observe how the teacher uses 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 of analysis (Andersson, 2001; Gough, N., 2002; Kump, Kasting & Crane, 2004; McNeill, 2000). All processes on Earth can be related to the lithosphere, hydrosphere, atmosphere and biosphere influenced by man, society and the technosphere. This is a model with roots in the Greek scientific history but still usable in learning for sustainable development (Helldén, Lindahl & Redfors, 2005; Persson, 2005; Skinner, Porter & Botkin, 1999). During the last twenty years, *Earth System Science Education, ESSE,* has been established dealing with environmental issues (Johnson, Ruzek & Kalb, 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.

In order to explain the model of analysis for teachers and the children 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).

Results and discussion

This is a part of an ongoing longitudinal doctor study and the examples from the video-sequences and interviews are tracked over time from year 2003 to 2006.

The increasing greenhouse effect

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

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?

Tom: 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.

Andy: 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?

Bob: The sea will get higher.

Teacher: What happens then with the people living near the beach?

Jessica: 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 application. 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 when they recorded lessons about photosynthesis earlier in the video. 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 as 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.

Non-polluting cars and other vehicles

In this study it is quite interesting to observe what is happening in between the different spheres and the young children's discussions. The pupils consider the exhaust from a vehicle. *How will it be spread? Will it come to the soil again?* The children are talking about buildings that are weathering and toxic substances and pollution entering the groundwater after rain. According to the pupils' homework when 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.

The questions were:
What do you mean with a bus adapted to the environment? What's the difference compared to a traditional bus?

Bob (2005): 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.

Hans (2005): 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.

Sonja (2005): 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 polluting the environment. Then you have used things growing in the nature. And it is not dangerous.

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 2003 to the next one 2004 and 2005. *The increasing green house effect* as a concept appears to most of the pupils in 2005 and the answers are related to non-polluting cars and other vehicles.

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

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

Bob (2005, May): 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 in consideration.*

Bob (2006, May): 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.

Here we notice that Bob is more determined in his answers from one year to another. Maybe this is a result illustrating learning for sustainability. Two pupils' answers about *the increasing green house effect* are caught as follows.

Hans (2005, May): I have heard about it but I don't know what it is.
Hans (2006, May): Something that is not good for the environment.

Sonja (2005, May): I don't know.
Sonja (2006, May): 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 techno sphere 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* (Österlind, 2004). 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 (Bruner, 1960), but hardly familiar with Socratic dialogue. One problem in environmental teaching is the difficulty to find only one right answer to environmental issues. There are environmental conceptions 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 system model. Her comment after looking at videosequences supporting this behaviour is:

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

The hydrological cycle

The following example from a transcript will illustrate how important it is to be in contact with environmental concepts early. In environmental learning there is often more than one correct answer and different aspects on more or less complicated issues.

The dialogue between the pupil and the teacher is taking place in the classroom:

Teacher: But what did you say? There are molecules in gasoline, too. Everything is built of molecules. Water consists of molecules. Shall we clarify the pollution and the gasoline? What did you say?

Sune: What did I say?

Teacher: Yes, what did you say?

Sune: It is very much I don't remember what I said.

Teacher: Yes you told us very much. When the pollution comes in to the water it stayed there. If the sun shines the water will evaporate. It will evaporate to the air and clouds and get rain. That's right! But you also told us it would be dirty.

Sune: Yes!

Teacher: But is it dirty when it evaporates as a gas?

Sune: That's a good question!

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 left 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.

Teacher: 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.

The dialogue continues as follows after the polluted water steam is transformed into raindrops:

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.

Teacher: It will be correct.

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 groundwater. Gradually they ask what happens in the hydrological cycle including environmental impacts in different stages.

Summary

Some pupils can see the connection between *the increasing greenhouse 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 lots of water when e.g. the sea will get higher. The children 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.

With examples from everyday life and other facts it is possible to give signals to the pupils about the environment (Österlind, 2004). They can argue about possibilities to change different habits in the technosphere in different ways, which reduce disturbance in the lithosphere, atmosphere and hydrosphere, and favorably affects the biosphere and human life. They start using scientific and technological concepts and try to see environmental applications and understand environmental concepts and relations between different concepts.

In our research the pupils use concepts and environmental relations in a dialogue with the teacher as we think Socrates did (Molander, 1996; Taylor, 1939). 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 between the different spheres in detail, e.g. on the atom and molecule level as well as the holistic level (Gough, N., 2002). Environmental learning must almost always deal with details as well as generalities.

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 (Hill, 1998, 1999). Some pupils, e.g. Sonja and Bob also put exhausts from vehicles in relation to *the increasing greenhouse effect* and the hole in the ozone layer.

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 stimulated recall the teacher has opportunities to discuss the student results in correlation to her intentions.

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 children and in the teacher's methodology (Andersson, 2001; Gough, N., 2002). New concepts and environmental relations are added to one after another as it is discussed in Bruner (1960).

Conclusions and implications

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 analyses we 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 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 the technosphere. Sometimes the discussion starts with details on the micro level and continues to a holistic level using environmental conceptions (Gough, N., 2002; Huckle & Sterling, 2001; von Wright, 2000).

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 (Aikenhead, 1996; Jenkins, 1996). The teacher consequently uses a Socratic dialog (Molander, 1996;

Taylor, 1939). She stimulates the learning following up the concepts step by step due to the children's growing interest (Bruner, 1960, 1996). It will create discussions with the pupils and between them (Vygotskij, 1986). Some questions they take home for further discussions with their parents and sometimes they have to solve problems in contact with somebody in the community or looking in the newspapers (Bliss, 1996; Dewey, 1916b).

The most interesting, in our point of view, is how very young children can discuss complicated environmental issues and find out the needs of changing technology as well as attitudes and lifestyle (Huckle & Sterling, 2001; von Wright, 2000). The teacher has to stimulate the communication in the classroom (Alexander, 2006; Molander, 1996; Rojas-Drummond & Mercer, 2004; Vygotskij, 1986). She must also give structure in learning and go ahead step by step based on the children's ability (Bruner, 1960). In many cases the dialogue continues outside school, when children are talking with their parents or other adults (Bliss, 1996; Dewey, 1916b, Lemke, 2001). The longitudinal approach in the study is worth following up what will happen using this model for older pupils (Helldén et al., 2005). We think the progress of learning in environmental issues for sustainable development has to influence different curricula in the future (Aikenhead, 1996; Jenkins, 1996).

We hope the impact of our study is interesting for curricula in environmental education and learning worldwide for sustainable development. It is a way of looking at environmental issues as a key subject to avoid marginalizing environmental learning and teaching. From our point of view learning for sustainability has to be based on how the technology and lifestyle in the modern society will influence the lithosphere, the hydrosphere, the 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. 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* (Johnson et al., 2000).

Today the work for 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 not take notice of the very high temperature until it is too late.

For further research it is very interesting to find out how young children can use environmental concepts and discuss more and more complicated environmental issues and even propose solutions (Gille, 2004).

References

Aikenhead, G. (1996) Science education: Border Crossing into Subcultures of Science, S*tudies in Science Education*, 27, 1-51.

Alexander, R. J. (2006) *Towards Dialogic Teaching: rethinking classroom talk*, 3rd Edition (York: Dialogos).

Andersson, B. (2001) *Elevers tänkande och skolans naturvetenskap: forskningsresultat som ger nya idéer* (Kalmar: Lenander).

Barnes, D. & Todd, F. (1995) *Communication and learning revisited* (Portsmouth: Boynton/Cook Publishers).

Bhaskar, N. (2003) Education for sustainable development: The Johannesburg summit and beyond, *Environmental, Development and Sustainability*, 5(1), 231-254.

Bliss, J. (1996) Piaget und Vygotsky: Ihre Bedeutung für das Lehren and Lernen der Naturwissenschaften, *Zeitungschrift für Didaktik der Naturwissenschaften*, 2(3), 3-16.

Board of Studies (2000) *VCE Environmental Science* (Carlton: Board of Studies).

Brundtland, G. (1987) *Our common future, The Brundtland report* (Stockholm: Prisma).

Bruner, J. (1960) *The process of education* (Cambridge: Massachusetts: Harvard).

Bruner, J. (1996) *The culture of education*, 2nd Edition (Cambridge, Massachusetts: Harvard).

Calderhead, J. (1996) Teachers: Beliefs and Knowledge, in: Berliner och Calfee (Eds) *Handbook of Educational Psychology* (New York: Simon & Schuster MacMillan).

Dewey, J. (1916a) *Democracy and education* (New York: McMillan).

Dewey, J. (1916b) *Demokrati och utbildning*, Swedish translation 1999 (Göteborg: Bokförlaget Daidalos AB).

Devine-Wright, P., Devine-Wright, H. & Fleming, P. (2004) Situational influences upon children´s beliefs about global warming and energy, *Environmental Education Research*, 10(4), 493-506.

Gille, S. T. (2004). Integrating Policy into Science in the Classroom: Three Case Studies on the Atmosphere. *Journal of Earth System Science Education,1,*

(Article + Case Studies), JESSE-04-300-07, http://jesse.usra.edu/archive/jesse04-300-07 .

Ginsburg, H. P. & Opper, S. (1988) *Piaget´s theory of intellectual development*, 3rd Edition (Englewood Cliffs, N.J.: Prentice-Hall).

Gough, A. (2002) Mutualism: a different agenda for environmental and science education, *International Journal of Science Education*, 24(11), 1201-1215.

Gough, N. (2002) Thinking/acting locally/globally: Western science and environmental education in global knowledge economy, *International Journal of Science Education*, 24(11), 1217-1237.

Grosslight, L., Unger, C. M., Jay, E. & Smith, C. L. (1991) Understanding models and their use of science. Conceptions of middle and high school students and experts, *Journal of Research in Science Teaching*, 28(9), 799-822.

Guthrie, W. & Keith, C. (1999) *Grekiska filosofer: från Thales till Aristoteles* (Nora: Nya doxa).

Helldén, G., Lindahl, B. & Redfors, A. (2005) *Lärande och undervisning i naturvetenskap: en forskningsöversikt* (Stockholm: Vetenskapsrådet).

Hill, B. (1998) *Der Methodbaukasten Ein kompendium von Methoden zur Erkennung und Lösung technischer Probleme* (Aachen: Shaker Verlag).

Hill, B. (1999) *Naturorientierte Lösungsfindung: Entwickeln und Konstruieren nach biologischen Vorbildern; mit 6 Tabellen* (Renningen-Malmsheim: Expert Verlag).

Huckle, J. & Sterling, S. (Eds) (2001) *Education for Sustainability* (London: Earthscan Publications Ltd).

Jenkins, E. W. (1996) The nature of science as a curriculum component, *Journal of curriculum studies*, 28(2), 137-150.

Johnson, D.R., Ruzek, M. & Kalb, M. (2000) Earth System Science and the Internet, *Computers and Geosciences*, 26(6), 669-676.

Jordan, B. & Henderson, A. (1995) Interaction Analysis: Foundations and Practice, *The Journal of Learning Sciences*, 4(1), 39-103.

Lemke, J. L. (2001) Articulating Communities: Sociocultural Perspectives on Science Education, *Journal of research in Science Teaching*, 38(3), 296-316.

Kump, L. R., Kasting, J. F. & Crane, R. G. (2004). *The Earth System*, 2nd Edition (New Jersey: Pearson-Prentice Hall).

McNeill, J. R. (2003) *Någonting är nytt under solen. Nittonhundratalets miljöhistoria (Kristianstad:* Kristianstads boktryckeri).

McNeill, J. R. (2000) *Something new under the sun: an environmental history of the twentieth-century world* (New York: W.W NORTON).

Molander, B. (1996) *Kunskap i handling* (Göteborg: Bokförlaget Daidalos AB).

Mortimer, E. & Scott, P. (2003) *Meaning making in science classrooms* (Buckingham, UK. Open University Press).

Musidłowska-Persson, A., Alm, R. & Emanuelsson, C. (2007) Cloning and sequencing of the Bet v 1-homologous allergen Fra a 1 in strawberry (Fragaria ananassa) shows the presence of an intron and little variability in amino acid sequence, *Molecular Immunology*, 44(6), 1245-52.

Novak, J. D. (1993) Human Constructivism: A unification of Psychological and Epistomological phenomena in Meaning Making, *International Journal of Personal Construct Psychology*, *6*, 167-193.

Odum, E. P. (1971) *Fundamentals of ecology*, 3rd Edition (Philadelphia: PA: W. B. Saunders).

Patton, M. Q. (2002) *Qualitative Research & Evaluation Methods*, 3rd Edition (London: SAGE, cop).

Persson, C. (2004) *Environmental learning for sustainable evolution in school and teaching.* Paper presented at the XI IOSTE Symposium 25-30 July 2004, Lublin, Poland.

Persson, C. (2005) *Learning environmental conceptions in primary school with a scientific approach.* Paper presented at the The fifth international conference of the European Science Education Research Association, ESERA 28 August-1 September 2005, Barcelona, Spain.

Persson, C. (2006) Nya former för lärande. Leken som ett redskap i lärandet i miljö i grundskolans tidigare årskurser, *NorDiNa*, 2(1), 58-71.

Rojas-Drummond, S. & Mercer, N. (2004) Scaffolding the development of effective collaboration and learning, *International Journal of Educational Research*, 39, 99-111.

Scharff, R. C. & Dusek, V. (Eds) (2003) *Philosophy of technology. The technological Condition* (Blackwell Publishing).

Sjøberg, S. (2005) *Naturvetenskap som allmänbildning - en kritisk ämnesdidaktik* (Lund: Studentlitteratur).

Skinner, B. J., Porter, S. C. & Botkin, D. B. (1999) *The Blue Planet: An Introduction to Earth System Science*, 2nd Edition (John Wiley and sons Ltd).

Taylor, A. E. (1939) *Sokrates: människan och filosofen*. (Stockholm: Natur och kultur).

Tiwari, G. N. (2003) *Greenhouse technology of controlled environment* (Narosa Publishing House).

UNESCO (2005) *Decade of education for sustainable development* (Paris).

van Driel, J. H. & Verloop, N. (1999) Teachers' knowledge of models and modelling in science, *International Journal of Science Education*, 21(11), 1141-1153.

von Wright, G. H. (2000) *Vetenskapen och förnuftet: ett försök till orientering* (Stockholm: Bonnier).

Wood, D., Bruner, J. & Ross, G. (1976) The role of tutoring in problem solving, *Journal of Child Psychology and Psychiatry*, 17(2), 89-100.

Vygotskij, L. (1986) *Thought and language* (Cambridge: MA: MIT Press).

Young, B., Noone, K. & Steffen, W. (Eds) (2006) *IGBP Report No. 55. Science Plan and Implementation Strategy* (Stockholm: IGBP Secretariat). Available online at: http://www.igbp.kva.se//uploads/IGBP-SP-2006.pdf (accessed 10 July 2006).

Österlind, K. (2004) Julias work on the green house effect, in: P. Wickenberg (Ed) *Learning to change our world?* (Lund: Studentlitteratur).