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16 Summary.

16.1 Background and aims

International documents like Tblis (SIDA, 1999) and Agenda 21 (1992) state that education is an important mean for the development of a sustainable society. *The World Commission of Environment and Development* (1987) states that teachers are important and that teacher training is crucial. In the Swedish national curriculum for science it is stated that pupils should develop the ability to use knowledge in science to support their arguments about environmental issues. There are several arguments for including science in the school curriculum. The democratic argument, which is relevant for this work, is that an understanding of science is necessary to participate in discussion, debate and decision-making about science-related issues in society. Millar (1996) questions if we really can prepare young people to a hold an informed view of such topics as genetic engineering, nuclear power and all kinds of environmental issues. According to Gräsel (2000) to behave in a way which promotes sustainability requires knowledge from three areas; knowledge in ecology, knowledge in how to act and social knowledge. Millar (1996) argues that there is a need to give curriculum priority to fundamental understanding on which more detailed knowledge required in order to grasp particular issues can be built, as require. One powerful model is the atomic/molecular model of matter emphasising the understanding of chemical reactions as rearrangements of matter. The ability to apply knowledge requires a stable conceptual framework.

The aims of this study are to investigate how science teacher students in a programme oriented towards the first seven years of school develop conceptual understanding relevant for environmental education and ability to discuss complex environmental issues during their training. Another aim is to relate the students' learning to their experience of the programme. It might be hazardous to draw conclusions about causes and consequences between explicit teaching situations and learning, but by describing how the students experience their own learning and the teaching you can discuss possible connections.

16.2 Framework

Environmental knowledge

In the study there is an analysis of international and national documents in order to describe "good environmental education". Research articles about environmental education are referred to. Knowledge in natural science is in that way put in a context and important science concepts for environmental education is defined. These are photosynthesis, respiration, and decomposition, cycling of matter, matter and energy. The concept of complexity is analysed and discussed in the study and the ability to discuss complex issues is defined as:

To

- realise that the parts form the whole and that the sum of parts might be different from the whole
- have an overview of the environmental issues
- use knowledge from several subject areas to describe an environmental problem
- use causes and consequences in explanations
- understand feed-back mechanisms
- identify values
- identify conflicts of interest

Learning

During the last decade two perspectives on learning have been widely discussed – the individual and the sociocultural perspectives. The individual perspective goes back to Piaget and the basic idea is that the individual constructs knowledge by processes of assimilation and accommodation (von Glasersfeld, 1995). The concept of conceptual change and how teachers can create situations of cognitive conflict is often discussed (Posner et al, 1982; Hewson, 1981). Solomon (1992) objects to the idea of conceptual change. Her objection is that when discussing a problem we can use a common sense language, a scientific language or a combination of these. It is not meaningful to require that students change from one way of thinking to another. They have to learn that the different languages are useful in different situations (ibid). Research has developed from mapping misconceptions to describing alternative frameworks (Driver & Easley, 1979). Strike & Posner (1992) described the original theory as overly rational and suggested that the learner's motivation and value of the subject material play important roles in a conceptual ecology. Demastes, Good & Peeebles (1995, 1996) have drawn on this and shown that if there is a conflict between the pupils' life world and the scientific theories it is impossible for the pupils to accept e.g. theories of evolution even if they cam learn them.

The sociocultural perspective on learning focuses on the process of communication (Cobern, 1998). There is a wide range of beliefs underpinning the sociocultural perspective – from a denial of the individual to descriptions of the importance of the context for conceptual learning. Several researchers argue that it is not meaningful to look upon learning from only one perspective (Leach & Scott, 1999; Sfard, 1998). It is necessary to create links between them. The theoretical framework of this study learning is seen as an individual process that is socially mediated (Andersson, 2001).

Context

It is accepted that individuals' ability to deploy conceptual knowledge depends upon the context (Brickhouse, 2001; Brown, Collins & Duguid, 1989; Caravita & Halldén, 1994). Wistedt (1994) writes that context is the pupils' cognitive construction of a situation. This means that a group of pupils can work together with the same task but act in different contexts depending on how they interpret the task. Caravita and Halldén (1994) point out the importance of being aware of what context you are in. Learning aims at developing ability to organise and separate between different contexts to increase the possibility to interpret the environment. The learner should develop consciousness of what context he/she is in.

Learning projects and intentionell analysis

Halldén (1982) describes how pupils in upper secondary school interpret and perform tasks in school. He describes how different learning projects can be identified among the pupils. The pupils are not aware of these learning projects themselves but they will decide how the pupils interpret the task. The learner's learning project can be expressed as her/his intentions with the education or the task (Halldén & Wistedt, 1998). An intentional perspective can be described as a link between an individual and a sociocultural perspective on learning. Learning is always somebody's learning of something but it has a social side. The situation sets limits for what counts as learning and knowledge in a specific situation. In an intentionell perspective human acts are considered as intentional and rational (ibid).

Teacher students in Sweden
Jönsson (1998) interviewed 100 student teachers in Malmö in programmes oriented towards grade 1-7 and 4-9 in school. The 1-7 students generally thought that they had enough subject knowledge to be able to teach science but asked for more contents concerning methodology and education. Wernesson (1992) found in a survey with students in the same programmes in Gothenburg that the most important reasons for choosing the programme was a wish to work with children and interest in the subject. The students expressed that an important characteristic of a good teacher is ability to create good relations with the children. Subject knowledge was seen as important, but not important enough.

Previous research – conceptions
Studies with young people show that they have common sense thinking about photosynthesis, respiration and decomposition. They do not see the processes as chemical reactions. It is difficult for them to integrate aspects of ecology, physiology, biochemistry and energy. Conservation of matter is not fully understood even after teaching. Many pupils consider breathing and respiration to be the same thing. Also older pupils find it difficult to grasp the idea of transformation of energy. (Barker & Carr, 1989a; Driver, Squires, & Wood-Robinson, 1994; Leach, Driver, Scott, & Wood-Robinson, 1996; Waheed & Lucas, 1992).

There are few studies involving university students or teachers. These have mainly focused on primary school teachers who are not specialised in science (Ameh & Gunstone, 1985; Kruger, 1990; Lawrenz, 1986). Eskilsson & Holgersson (1999) showed that many teacher students in science improved their understanding of photosynthesis after a basic science course. However as many as a third of the students still used common sense ideas, like the plant sucks water from the soil or it takes matter from seed potato, to explain where seed potatoes get matter to build new potatoes from. Carlsson (1999) showed that among student teachers it is possible to categorise several ways of thinking about photosynthesis, recycling and energy. A main finding is that there is a crucial division between those students who think in terms of transformation and those who do not in how they can discuss phenomena like a closed ecosystem.

Previous research – ability to discuss complex issues

Boyes & Stanisstreet (1992, 1993, 1994, 1997, 1998) and Boyes & Stanisstreet & Chambers (1995) investigated childrens' and student teachers' understanding about causes and consequences of two major environmental problems – the depletion of the ozone layer and the green house effect. Dove (1996) investigated student teachers' ideas about the green house effect, the depletion of the ozone layer and about acid rain. The issues are complex and include understanding of several concepts in natural science. The researchers all found common sense thinking also among university students. There seemed to be better understanding of the ozone layer than of the greenhouse effect. All researchers found that many students have naive ideas about environmental problems. For example they seemed to think that if something is environmentally friendly it is good to everything in the environment. Many students thought that catalysts and lead-free petrol could help to decrease the greenhouse effect.

Gomez-Granell (1993) was interested in finding out how complex students understand the relationship between actions and consequences concerning energy. By asking the students to combine different actions with a number of consequences she found that many students did not have much complex thinking. They had a tendency to choose more general consequences like economy or emissions to the atmosphere instead of scientific explanations. They did not identify a chain of events. By interviewing some students it was confirmed that there was much confusion in the use of scientific and technical concepts.

16.3 Research questions

1. How do the students experience the teaching and their own learning in the science courses?
2. How do the students develop understanding of some science concepts relevant for environmental education during the first five terms be described?
3. How does the students' ability to discuss complex issues develop?
4. Is it possible that the answer of question one can shed light on question 2 and 3?

In the previous section some important science concepts for environmental education were defined. To understand a concept like photosynthesis means to be able to explain e.g. how biomass is built up in plants. It is also important that the concepts can work as tools when the students discuss environmental issues. To understand environmental issues also requires ability to put them in a larger context and to realise that they are complex. Some aspects of complex reasoning were defined in the previous section as well. It is difficult to investigate how and why learning takes place. It is not possible to draw conclusions from explicit events in a teaching situation and the students' learning. But by describing how the students experience their own learning and the teaching you can discuss possible connections.

16.4 Methods and samples

The research reported here, builds upon data from a two-and-a-half-year longitudinal study with student teachers accepted to a teacher education programme on 3.5 years oriented towards mathematics and science for primary school (age 7-13) in 1999. To be accepted to the programme natural science from upper secondary school is required. During the first term the students took an integrated science course (NO1) of 10 credits (10 credits correspond to 10 weeks full time studies) organised as PBL[18]. The course contents were about ecology,

[18] PBL = Problem Based Learning. In PBL the students work in small groups and they get cases to solve. A very structured problem-solving model – the seven steps is used.

astronomy, meteorology and environmental science. During term four and five the students took a 20-credits course (NO2) in science organised as four separate courses on five credits each − physics, chemistry, human biology and technology. Most of the environmental contents were concentrated to the first science course, but relevant environmental issues were supposed to be included in NO2. Concepts like conservation of matter, energy and respiration were dealt with.

Design

Rickinson (2001) points out that most surveys about what knowledge people hold in environmental science are short-term studies performed with students in school. There is a need for long-term studies. Gunstone & White (2000) argue that longitudinal studies can contribute to the understanding of what factors influence development of conceptions. Studies with university students are often short-term studies in the beginning of the programme. I found it unfair to draw conclusions about the students' conceptual understanding from what they learnt in a science course in the first term. I wanted to see if the knowledge was consistent and if the students developed further in the next science course. Therefore I chose a longitudinal study. Data were mainly collected through questionnaires and interviews with students and teachers. From the questionnaires you get an overview of what the students know and understand. Through the clinical semi-structured interviews the knowledge of what patterns of learning there are and how these are related to the course contents and what is going on in the course are more deeply understood (Duit, Treagust, & Mansfield, 1996). In the questionnaires you can get an overview of what general difficulties there are in the student group. But the students can experience the questions to be out of context. This might explain if they show common sense thinking.

All students answered a questionnaire three times. A small group of students were interviewed three times. All the teachers were interviewed after the courses. Ten hours of PBL-work in one student group were observed.

A teacher facilitates the group-meetings. The method was first used in medical training in Canada and in the Netherlands.

Table 1. Overview of the data collection.

	Term 1. Before NO1	Term 2 After NO1	Term 5 After NO2
Questionnaires	n = 60	n = 49	n = 47
Interviews	20 students	14 students 4 teachers	14 students 12 teachers
Other	Observations 10 hours during the course	Minutes from meetings written by students	Lab.reports Project reports

Questionnaires

In the questionnaires the students answered questions which aimed at testing their understanding of photosynthesis and respiration in all three questionnaires and of decomposition and combustion in questionnaire 3. To test if the students include several subject-areas in an issue they were asked to draw concept maps about where the food you eat comes from and where it goes in the first two questionnaires and about cars and the environment in questionnaire 3. They also got questions about causes and consequences of the depletion of the ozone layer and the greenhouse effect. In questionnaire 2 and 3 the students were asked to explain the concept of the greenhouse effect. In the third questionnaire some questions were added to test how the students look upon scientific models.

Interviews

In the interviews the students discussed a newspaper article, which deals with the question of whether it is ethical to use surplus heat from a crematorium in the far heating system. In a city the public administration suggests that heat from a crematorium should be used for environmental and economical reasons. A bishop objects, as he does not want to sit in the heat from his dear and near ones. It is an authentic situation with aspects of natural science, social science, technology, environment, economy and ethics and the issue is emotional. In the interviews the students were asked to describe the situation. In interview 2 they also posed questions as if the article was a PBL-case and they told how they would work with such an issue in school. They were explicitly asked what happens to the bodies in a crematorium and in an earth burial. In interview 1 the students were asked about why they had chosen this teacher programme and about their expectations of the programme. In interview 2 the students and the teachers were asked about the group-work, the cases, the individual work and the learning outcome i NO1. After NO2 the students and the teacher told about the courses, how the work was organised, the learning outcome etc. All the interviews and observations were recorded and transcribed word by word.

Analysis of data

1. How do the students experience the teaching and their own learning in the science courses?

From the interviews the group-climate in the PBL-groups was described. From how the students expressed expectations of the programme and how they experienced the relevance of the contents in the courses their learning projects were interpreted. From how teachers described the aims of the courses and the students' learning their learning projects for the students were interpreted.

2. How do the students develop understanding of some science concepts relevant for environmental education during the first five terms be described?

The answers in the questionnaires were categorised. Coding schemes were set up and the transcripts from the interviews were coded. In the interviews the students' conceptual understanding was analysed in two ways – if there was correspondence between the answers in the questionnaires and the explicit answers of what happens with the dead bodies and if/how the students' understanding was revealed when they talked freely about the situation. In the third interview a closed ecosystem and what goes on in it was discussed. The statements when discussing the article spontaneously, as a PBL-case and as a situation in school were compared.

3. How does the students' ability to discuss complex issues develop?

In the study the following aspects of ability to discuss complex issues were tested:

To use causes and consequences when discussing a complex environmental issue

In the questionnaires the students marked if they think that 12 statements about the depletion of the ozone layer and the greenhouse effect are correct or not. I the interview transcripts situations when the students used causes and consequences were identified.

To explain a complex concept
The students' explanations of the greenhouse effect were categorised.

To show awareness of the fact that complex issues involve knowledge from several subject areas.
In questionnaire 1 and 2 the students drew concept maps to illustrate the question *Where does the food you eat come from and where does it go?*. In questionnaire 3 the students drew a concept map to illustrate the title *The car and the environment*. In the pictures a number subject areas were identified. In the interview transcripts the number of subject areas mentioned by the students were counted.

To identify the conflict of interests in the newspaper article and to identify the underlying arguments
In the transcripts it was noted if the students mentioned the conflict of interests in the article. The students were asked to find arguments for different actors in the situation.

4. Is it possible that the answer of research question one can shed light on research questions 2 and 3?

After identifying the students' learning projects and putting together the results of their knowledge the theories of intentional learning and interpretation in several contexts were applied to explain the students' learning.

16.5 Results

How do the students experience the teaching and their own learning in the science courses?
It became apparent that most students had chosen the programme because they wanted to work with children. Few students mentioned an interest in science as a reason for becoming a science teacher. The students expressed that they acquired subject knowledge sufficient to teach in primary school and they asked for more methodology and education. They explained how they found some of the contents in the

subject courses irrelevant for their future profession. For example they did not see the purpose of writing chemical formulas. One of the questions in the third questionnaire tested if the students could write the reaction formulas to explain why oil with high sulphur contents can cause acid rain. Only three students (out of 47) could do this. When asked why in the interviews the students said that chemical formulas are something you learn by heart, it is better to understand than to learn to write formulas or that you do not need this to teach young pupils. No one seemed to consider chemical formulas as tools for your own understanding. The students often came back to the need of learning how to explain phenomena to the children. No one mentioned the importance of building conceptual understanding among the pupils.

The students' learning projects were interpreted from the interviews. All students had a learning project which aims at becoming science teachers for young pupils in school. Parallel to this two other learning projects were identified. All students wanted to pass the exams and all students wanted to understand the contents. But to some students these projects were more important than to others. One student expressed clearly that she studies mainly to pass the exams. She tried to figure out what the teachers found important and what would be tested in the exams. She made an effort to remember the right answers in the interviews while talking about the closed ecosystem or what happens in the crematorium. She was well aware of her own strategies and in the last interview she herself somewhat questioned her strategy. Three students talked several times about the importance of understanding the subjects and of acquiring models that could help them to understand new situations.

In PBL in NO1 the students were able to reconstruct what they already knew about a subject and to choose literature on a level relevant for their prior knowledge. PBL was good for students in the sense that their self-esteem increased and that they felt that the learning process is something they took responsibility for and they adopted skills, which will be useful as a teacher. According to the teachers the students learnt to pose questions, seek information, to structure it and to present it. All students appreciated the method very much. They enjoyed learning and felt that they made great progress. Several students expressed that their prior knowledge in science was poor. They told that they understood very little from science lessons in school and that they found science difficult and boring. At the same time it was apparent the students did not work with problem solving. Instead they tried to figure out what the cases were about and to pose some questions to which they could find correct answers. Some problem-oriented questions were posed but they were not followed up. There were great opportunities to challenge each other's ideas and to develop critical thinking in the group work. But instead the students were very kind to each other and seldom questioned or criticised each other's contributions. The students knew from schoolbooks and from what they saw in school what is a relevant level for primary school teachers. The teachers tried to raise the level but the students were strong as a group and negotiated a level they found appropriate. On the other hand they learnt to listen to each other and to create a friendly atmosphere in the groups. The students found the work in consistence with their learning project. They felt that they developed skills that are relevant for the teacher profession.

In NO2 the students went back to the role as pupils. They found the contents difficult and they worked hard to pass the examination except in technology. Several of them told that they tried to cram facts into their heads. Occasions on which the students were supposed to discuss problems relevant to the course contents had a tendency never to take place. The students felt that the time was better used for preparation for the examination. The teachers did not follow up the discussions. The students asked for more contents related to school. According to the teachers the contents and the activities were chosen to prepare the students for the work as teachers. But the students had a picture of what you can do in school, which was not in accordance with what they experienced in the subject courses. Several of them did not see that the activities they performed themselves could be transformed to a level appropriate for the children in grade 1-7 in school.

In the chemistry and physics course many students more or less had a learning project aiming at passing the exams. The teachers wanted the students to develop scientific thinking. They focused on understanding rather than rote learning. They wanted the students to acquire a conceptual understanding, to work with models, to understand the role of experiments etc. It is obvious that there was a gap between the students' learning project and the learning project the teachers had for the students. According to Wistedt (1998) there is a risk for rote learning when there is discrepancy between the students' and the teachers' learning project.

The technology course was different. It was not a pure science course but dealt with systems for food, energy and water in society. One of the aims was to change the students' view of the school subject technology from a workshop subject to a view in consistence with the national curriculum. In the course the students did several study visits and they worked with problem solving activities and project work. The curriculum was thoroughly discussed and all the activities were discussed from the students' perspective and how they could be used in school. In this course the students and the teachers expressed the same learning projects.

How can the development of students' understanding of some science concepts relevant for environmental education during the first five terms be described?

According to the questionnaires a majority of the students did not grasp either the idea of photosynthesis or of respiration or decomposition completely and did not express that photosynthesis and respiration are chemical reactions that take place in the cells. Most students explained combustion in a scientific context though. If the answers to respiration, decomposition and combustion are compared it is apparent that the students' answers were situated. Only six students showed that they had a general understanding, which means to see that, the processes as basically the same. Typical answers were that in respiration matter is transformed to energy, in decomposition matter is transformed to soil and in combustion matter is transformed to carbondioxide and water. The students interpreted the questions in different contexts. This was clarified in the interviews. Several students mentioned that the question about combustion felt like an examination question in chemistry and then it was natural to answer in a scientific context. The question about decomposition dealt with a compost heap and the students said that you see the heap and you know that you get soil. The answer can be described as a common sense context.

Some students who answered the questions about respiration and photosynthesis in a scientific context in the second questionnaire gave short explanations, which did not answer the question in the third questionnaire. The interviewed students found these answers more professional. My interpretation is that they gave an explanation, which they found appropriate for school. It was apparent that the students quickly interpreted the questions in a context and answered in this context no matter of what was actually asked for. The students generally did not separate between different contexts.

In the discussion about the crematorium the students were asked what actually happens to the bodies if you burn them and if you earth bury them and in the third interview a closed ecosystem was discussed. The answers did not fully correspond with the questionnaires. Some students who answered in a school context in the questionnaire could explain the concepts in a scientific context when they were encouraged to do so. Some students who started out with very fragmented ideas could sort things out with my help. But even if the students generally answered better in the interviews at least at some points, some students who answered well in the questionnaires seemed to find it difficult to apply the knowledge in a more unstructured discussion. All students found it difficult to reason about events in the closed ecosystem. The difficulties, which appeared in the questionnaires, remained in the interviews. In the study a number of cases are described in more detail.

To summarise:

- Most students had a particle conception of matter.
- The student group had two models of a chemical reaction – a model of decomposition and a model of rearrangement of atoms. The word decomposition was confusing.
- Energy was a difficult concept for several students.
- It was difficult for several students to use the concepts in an applied situation like the closed ecosystem or the crematorium.
- Few of the students included microorganisms and/or gas-exchange in an applied discussion.
- Generally the students found it difficult to integrate aspects of photosynthesis, respiration and decomposition to reasoning about ecocycles.
- The students' conceptions were occasionally challenged in the interviews and they took a step forward.

- Several students but not a majority developed conceptual understanding in the science courses.

How does the students' ability to discuss complex issues develop?
According to the questionnaires many students deployed a more complex conception of the greenhouse effect after the science courses. There were fewer answers indicating a disability to separate between depletion of the ozone layer and the greenhouse effect. More students included absorption and re-radiation in the greenhouse gases to explain the increase of temperature. The number of correct marks in the statements about causes and consequences of the depletion of the ozone layer and the greenhouse effect increased in the second questionnaire and then decreased some in the third questionnaire. Literally all students knew in the third questionnaire that there is a natural greenhouse effect and that CFC:s can damage the ozone layer. A majority of students believed that catalysts in cars are helpful to the greenhouse effect which according to Boyes & Stanisstreet (1992, 1993) is a naive view. The students included more subject areas in the pictures of food in the second interview and even more subject areas in the question about the car in the third questionnaire. It was striking though that the areas included to a great extent were related to the personal lives of the students. For example in the question about the car and the environment many students included items in the pictures relating to what a car meant to them personally. Only a few students included infrastructure, international agreements or legislation.

When asked to comment on the article about the crematorium most students expressed a personal opinion. Only few students used arguments from natural science to support their standpoint. Typically they answered almost in the same way in all three interviews. They were more elaborate in the third interview but basically they used the same arguments. Few of the students knew anything about the principles for far heating in interview 1. In the technology course the students visited a far heating plant, but several students had not caught the idea of far heating in the third interview either. Several students answered emotionally. Some of them realised this in the last interview and expressed that there is a contradiction between science and emotions. To some students this meant that they found it OK to use the heat in the dwellings connected to the crematorium. Some students expressed the feeling of having somebody circulating in the radiators. Several students supported their arguments for or against reuse of heat with religious arguments. If you are religious you are against and if you are not you are for the reuse of the heat. One student changed his opinion in the third interview and used science arguments to support this.

No student brought in reasoning about causes or consequences. Only two students brought up the conflict of interests in the article but several students talked about their own conflict between emotions and scientific knowledge. When asked to consider the article as a PBL case most students asked all sort of questions about the environment, economy, infrastructure etc. The questions they asked though were more of the kind *What is the purpose of this case?* and less of the kind *What do I need to know to understand the issue?*. When asked how they would deal with it in school several students discussed the conflict of interest and they suggested teaching strategies, which can help the children in decision making, but they did not see this as a question of knowledge. It was apparent that the students were not used to discuss issues where there is a need to apply conceptual understanding.

In the study a number of cases are presented to describe the different ways in which the students discussed the article.

Is it possible that the answer of research question one can shed light on research questions 2 and 3?

The learning projects decided how the students interpreted the questions in the questionnaire and also how they interpreted the whole programme. They seemed to judge the contents of courses after the relevance for them as teachers. If they found that that the contents were not relevant they learned by heart to pass the exam. The students did not seem to see that the purpose of the courses was to help them to understand the world better themselves but rather how they could learn to explain some scientific phenomena to children. They learned some science and they learnt to appreciate science but they did not see the point in conceptual understanding. One student answered all my questions as how he would explain to children. When I for example asked questions including the concept of energy he answered that this would be too difficult for children so therefore he would never bring in that concept in his own teaching. It was impossible to make him express his own conceptions. This student did not develop conceptual understanding according to the questionnaires. The student whose learning project was interpreted as to pass the exam did not develop conceptual understanding very well either. Her learning project seemed to be an obstacle for her learning. For three students the learning project was interpreted as to understand. These three students all showed that they have a general understanding of the chemical processes respiration, decomposition and combustion. They used a model of rearrangement of atoms to describe a chemical reaction and they reasoned quite well about the closed ecosystem applying their conceptual understanding. But not even these students saw any point in knowing how to write chemical formulas.

16.6 Discussion

Discussion of the results

It seems like the students developed limited ability to use science in discussing and arguing in a complex environmental issue. A reason for not using science may be that they did not develop a firm conceptual framework, which according to Gräsel (2000) is necessary for ability to apply knowledge in new situations. In the PBL groups the students worked with cases which gave them the opportunity to discuss the issues from different perspective and to challenge each other's ideas. From interviews and observations it is obvious that they did not challenge each other as expected but instead strove to reach consensus and create a friendly atmosphere in the groups. The social response was more important than the cognitive, which is earlier described by Hewson (1981). The group sessions in PBL were very informal. The students worked together with peers and the language was like every-day language in which some natural science was used. The teacher took a very passive role. Therefore the students were very much left working within the limits of themselves and their peers. At lectures and lab work the teachers took the opportunity to model examples and questions to which the students could respond and critique though. In the last science course (NO2), with exception of technology, several students went into a role as pupils and their main goal was to pass the exams.

It is apparent that the students' knowledge was situated and that they could not distinguish between different contexts, which is important according to Caravita and Halldén (1994). In the interviews the students moved between different contexts. They were given an article from a local newspaper thus indicating an everyday context and then they were expected to answer in context of natural science. When they were asked about PBL and school they are put in new contexts and they answered differently. They are to become teachers and when asked about how to work with a dilemma in school they immediately suggested teaching strategies but no knowledge content. The students did not learn science well enough to use scientific knowledge when discussing a complex environmental issue. The teaching did not treat the linkages between scientific and non-scientific aspects specifically, and it is not therefore surprising that the students did not find it particularly easy to make these links.

I am convinced that the students could develop both a better conceptual understanding and ability to discuss complex issues if they had seen the point in it. A main finding is that the students unconsciously construct learning projects, which will decide how they interpret both the tasks they are given and the relevance of the contents in the subject courses. The learning project will influence what the individual students actually learn. According to the teachers the students are ambitious, creative and positive but have bad prior knowledge. They ask many questions and they want to learn. As rational persons they judge what they see in school and they prepare themselves for the coming profession.

How this study contributes to the research field of education

In this study it is shown how complicated it is to describe a person’s conceptual understanding and that there is no connection between how complex a person looks upon an issue and this person’s conceptual understanding. In the study a number of cases are described with respect to conceptual understanding and ability to discuss complex issues. The descriptions are related to the interpreted learning projects. One finding is that it does not matter how well you teach if the students do not find that the contents are in accordance with their learning project. The study is a longitudinal study and illuminates learning over time which according to Gunstone & White (2000) is necessary to acquire better understanding of conceptual acquisition. The study deals with teacher education. Very little is known about what teacher students learn in subject courses (Anderson & Mitchener, 1995; Cochran & Jones, 1998). The study tries to connect teaching and learning.

Implications for teaching

Suggestions for teaching:

- Discuss the learning projects with the students and with each other.
- Make the students aware of the different contexts they use.
- Decrease the amount of contents so that the students have time to work with their own understanding to avoid rote learning.
- Find new ways to examine the students' knowledge. It can not be reasonable that people who are to work with development of knowledge among pupils cram their heads with facts to pass a written exam.
- Relate the students' answers to how we know that pupils in school express understanding of the discussed concepts. This would also make the teacher students feel that the education is related to their future profession.
- Work with authentic cases where the students explicitly have to define scientific and non-scientific knowledge and to link these aspects.

Natural science for sustainable development?

Science teachers need to have an overview of the environmental issues and to be familiar with international and national documents concerning environmental education. Their special competence is to have knowledge in science which includes a stable science conceptual framework in order to help the pupils to develop scientific knowledge.

The students in this study have learnt about causes and consequences of some major global environmental issues. The issues have been treated mainly from a natural science perspective. They are not familiar with the international agreements and they have not discussed what environmental education is about. It is doubtful if most students have developed such fundamental understanding on which more detailed knowledge can be built as expressed by Millar (1996). The students are not aware of these aspects of the teacher work. They have worked in school regularly during the programme and they have faced other kinds of problems such as; how you can create a good working situation in the classroom, how you can help children with special needs, how you can find activities in which the students take an interest etc. The students have never felt that their science knowledge has not been good enough. They have discussed neither science education nor environmental education with the teachers in school. There is a risk that the goals of the international documents like Tblisi (SIDA, 1999) and Agenda 21 (UNEP, 1992) are far too optimistic (Oulton & Scott, 1995). Oulton & Scott write that there so many demands on teachers and there is a need for them to develop several different competencies to manage work in school.