Tuula Keinonen

PRIMARY SCHOOL TEACHER STUDENTS' VIEWS OF SCIENCE EDUCATION

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Abstract

The study explores primary school teacher students’ explanations connected to physics, and the students’ experiences in science education. The students’ physics explanations and views of science education were examined in the context of Science and Technology Education in the primary school teacher education. Science education includes science and science instruction as also learning. The study deals both with students’ language and experiences in science education in order to formulate a coherent image of the students’ views of science education. The instructional context is taken into account from the point of view of science education and especially of Science-Technology-Society (STS) education. The present study aims to create an understanding of the students’ views and to capture the factors in science education which the students have highlighted. On a larger scale the analysis of the study aims to promote science education in Finnish teacher education, but also in the Finnish primary school.

The theoretical framework of the study is based on the contemporary view of science education and its practises, and on STS education, which are applied to the pedagogical solutions and to the contents of Science and Technology Education. In accordance with the modern view the students are seen as active participants in the actual instruction-studying-learning-process. In accordance with the principles of STS education students as future citizens are also seen as active participants...
in the activities in the society. In addition, the inquiries and hands-on experiments in science education are emphasized. The study focuses in more detail on the views of science education which are seen as background knowledge for further development of the education under consideration in line with human constructivism. The theories and studies concerning the views of science education are presented, and the framework for analysing the views is based on the literature review. This framework highlights the traditional and contemporary views of science education. The theories and studies of reasoning are also presented and the framework for analysing the explanations is based on the literature review. The framework for reasoning brings into focus everyday knowledge and scientific knowledge.

For exploring the relationship between the primary school teacher students and science education, two different case studies consisting of pre- and post-questionnaires and narratives were conducted with the same students’ group in Science and Technology Education. The first one dealt with the explanations of physics phenomena in the beginning and at the end of the physics course in Science and Technology Education. The phenomena in the questionnaire dealt with mechanics, thermodynamics, optics and electricity. The instruction was not designed for the purposes of this study, but the effects of the existing course had been under consideration. The students’ explanations were recorded on Atlas-ti program and analysed qualitatively by using a data based discourse analysis.

The students’ explanations remained weak and sometimes inconsistent. The students used both everyday knowledge and scientific knowledge in their explanations, but also knowledge in between these two types. Some of the reasoning sounded like scientific knowledge but was expressed by using everyday knowledge. On the other hand, some of the explanations were everyday knowledge although correct scientific concepts were used. Reasoning was carried out mainly by the aid of everyday knowledge. The most advanced justifications expressed by the aid of scientific knowledge were found in the issues concerning mechanics and electricity related phenomenon. In the cases concerning light and heat the students used mainly everyday expressions.

The second case study dealt with narratives which the primary school teacher students wrote after their Science and Technology Education courses. They were asked to write a one-page-story. No
other instructions were given. The narratives were recorded on Atlas- ti program and analysed qualitatively. Themes in the narratives were searched. The students chose three different ways to describe their thoughts on education. One group reflected their own thoughts and actions. The second group evaluated the education by highlighting the contents and teaching methods of the education. This group reflected very little on their own role. The third group of the students commented on the education. They described what had happened at what point but gave little information about their own ideas concerning the contents or pedagogy. The students also wrote about science and science instruction and these themes were chosen for further analysis. In summary, the students saw science from four different viewpoints: contemporary, practical, pedagogical, and traditional. The views were, however, multidimensional. The views of science instruction were either traditional, process like or contemporary. Those students who reflected on education had more often a contemporary view of science and of science instruction. The students who evaluated or commented education had more often a traditional view of both science and science instruction. The students who had a contemporary view of science had also more often a contemporary view of science instruction.

Finally, the possible dependence between the views of science instruction and the type to explain physics phenomena was explored. Five different types of students related to the views of science and science instruction and the change in the type to reason physics phenomena were found. In summary, the students who had the traditional view of science or science instruction did not change in their reasoning types as a result of the education. However, the dependencies are more complicated and oversimplification has to be avoided.

The present study can be used as a framework for developing science education in teacher education, and the study sets further challenges for science education studies. The study provides a view of science education among primary school teacher students. The results are viable in the development of Science and Technology Education and have already been taken into account in the new curriculum. In addition, the suggestions in this study should be taken into account in teacher education and developmental work of the curriculum.
Tuula Keinonen
LUOKANOPETTAJAOPISKELIJOIDEN NÄKEMYKSIÄ
LUONNONTIETEISTÄ JA NIIDEN OPETUKSESTA JA
OPPIMISESTA


ISSN 0781-0334

Avainsanat: luonnontieteiden opetus, STS opetus, näkemys
luonnontieteistä, näkemys luonnontieteiden opetuksesta ja oppimisesta,
arkitehtuuri, tieteellinen tieto, luokanopettajakoulutus, diskurssi,
narratiivi

Tiivistelmä

Tutkimuksessa selvitetään luokanopettajaopiskelijoiden fysiikan
ilmioihin liittyvässä käytännossa käytämän kielen luonnetta ja opiskelijoiden
kokemuksia luonnontieteiden opetuksesta ja oppimisesta
Luonnontieteet ja teknologia – koulutuksen yhteydessä. Tavoitteena
on muodostaa kuva opiskelijoiden näkemyksistä luonnontieteiden
opetuksesta ja oppimisesta. Erityisesti näkemyksistä tarkastellaan
opetuskontekstissa, jossa on huomioitu luonnontieteiden nykyläiskäytysten
mukainen opetus ja luonnontieteet, teknologia ja yhteiskunta (STS) –
opetus. Tutkimus pyrkii ymmärtämään opiskelijoiden näkemyksiä ja
läytämään niitä luonnontieteiden opetuksen tekijöitä, jotka opiskelijat
ottavat esille. Laajemmin tarkasteltuna tutkimus pyrkii edesuuttamaan
suomalaisia opettajankoulutusta ja peruskoulun alempien luokkien
luonnontieteiden operusta.

Tutkimuksen teoreettinen viitekehys perustuu nykyaikaiseen
käsitykseen luonnontieteiden koulutuksesta ja sen käytännöistä sekä
STS – opetuksen, joita on noudatettu suunniteltaessa Luonnontieteet
ja teknologia – koulutusta. Nykyisen käsityksen mukaan opiskelijat
toimivat aktiivisesti opetus-opiskelu-oppiminen – prosessissa.
STS – opetuksen periaatteiden mukaisesti opiskelijoita pidetään
tulevina aktiivisina kansalaisina. Lisäksi koulutuksen aikana on


Toisessa osassa tarkastellaan luokanopettajaoipiskelijoiden kirjoittamia narratiiveja. Opiskelijat kirjoittivat Luonnontieteet ja teknologia – opinnoistaan yhden sivun mitaisen tarinan opintojen jälkeen. Tarinan kirjoittamista ei ohjastettu vaan haittiin niitä asioita, joita opiskelijat itse nostavat esille. Opiskelijoilla oli kolme


Tätä tutkimusta voidaan hyödyntää luonnontieteiden koulutuksen kehittämiseen opettajakoopetuksessa. Tutkimus tuo uusia haasteita kouluttajien ratkaistavaksi. Tutkimus antaa kuvan luonnontieteistä
luokanopettajaopiskelijoiden keskuudessa. Tulokset ovat merkittäviä ennen kaikkea Luonnontieteet ja teknologia –koulutuksen kehittämisen kannalta. Tuloksia onkin jo hyödynnetty uutta opetussuunnitelmaa laadittaessa. Lisäksi tutkimuksen tulokset ja ehdotukset voidaan ottaa huomioon myös muualla opettajankoulutuksessa sekä opetussuunnitelmien kehittämisessä.
Acknowledgements

By twelve-forty-five it was all over. On Monday morning the report has been completed. The path of this research work was long. I have to go back to year 1997 when I expressed my wish to work in the Faculty of Education. In the following spring I received a message to Strasbourg from the faculty: “We have a vacancy which you could apply”. Because of this message I started my career in education in 1998 after the return from France. Although leaving physics was not easy, from the first days onward I felt myself welcome and it helped me to adjust. I started the design of this study in 1999 and now in 2005 the work has come to its end. In these years many events, also hard and sad, the whole spectrum of human life and children’s growth to adolescents have taken place. The work has waited for long periods to be continued. Finally, in the autumn 2004 I decided to leave all other tasks and to concentrate on the writing process of this report. Now it is finished, and leaves me free to continue “real” research work.

I am very grateful for Professor Leena Aho for trusting in me in many tasks and for the guidance at the beginning of this study. I also thank her for the interest to read my draft at its final stage, although she had left the university. Her advice helped me to correct the work and to trust that it will be a Doctoral dissertation. Besides Professor Leena Aho my supervisor Professor Marja-Liisa Julkunen has also guided me to obey the traditions of educational sciences which in many ways differ from those in physics. I thank her for the guidance at every stage of the process, and at the final stage for the answers to my rather stupid questions. I also needed guidance from many other teachers in the faculty to be able to manage with the qualitative research traditions. I express my gratitude to all of them. It certainly has not been easy to guide a natural scientist to the educational way of thinking.

At the final stage of the study, Professor Sanna Järvelä, University of Oulu, and Professor, Dr. Reinders Duit, University of Kiel, read my last draft and provided useful comments and suggestions for the manuscript of my Doctoral dissertation. Their competent advice helped me to finish the dissertation. I would like to extend my thanks for their valuable work.

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To carry out narrative research had many difficulties. Discussions with Eeva Kohonen helped me to understand this kind of research. Eeva found for me a lot of material concerning narrative research when carrying out her own study in economics. She helped me to outline my study. Probably I would not have understood the narratives without the discussions with Eeva. There was also other kind of help which my friends offered during the research process. Helena Tuononen often tried to get me away from my work to take a break. Unfortunately she did not always succeed in it. I am also grateful for Kristiina Leinonen who always came when we needed help at home.

The process of preparing a thesis is an intensive process even though it happens for the second time. I can not ignore my experience in writing scientific text which has made the process probably easier for me than for other Doctoral candidates. But I will have to remind the reader that the traditions of two separate domains are somewhat different. I still learned a lot during the process which has been encouraging for me. Learning new was a challenge of this work. But an intensive work also takes time and energy away from something else. Mainly it was my friends and my family who were left aside. I have never needed to give up things which I have wanted to do.
Neither my husband Leo nor my children Katri, Antti or Eetu have demanded it. They have been with me in many situations including the life abroad. Although I sometimes have been afraid of how they manage, they have shown an excellent ability to accommodate. When I started this study, Katri was 13, Antti 11, and Eetu 8. Now, Katri has passed her matriculation exam and has already left home. Antti has been in the upper secondary school for one year and Eetu has left the primary level of the comprehensive school. As I wrote my work in our living-room, I could participate in childrens’ school attendance at the same time. Some of their exercises in mathematics were very burdensome for me to help them with as although I was present my thoughts were in another world. Sometimes I was very angry because of their interruption. Thus, my sincerest appreciation goes to my family. My special thanks go to Leo, who has been by my side all through these years. He has been the listener who has helped me manage in different tasks. He took more responsibility of the duties at home and especially of the transportation of the athletes of the family. My thanks go to our children, too. They have grown up in spite of my research to adolescents who will be able to manage in their life.

Joensuu, April, 8, 2005

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It was the darkest time of the year when I started the writing process of this study.

Das Schönste ist doch, dem Mitmenschen alles so leicht wie möglich zu machen. Mensch sein heißt, sich das Mitfühlen und Mitleiden mit den Menschen bewahren.

Albert Schweitzer
I Introduction

This is a story about my students’ experiences concerning science education. This inquiry is most important for me personally, firstly because I am responsible for the studies under consideration, and I am also one of the teachers. Secondly, the framework of Science and Technology Education does not exist elsewhere in the same form. Science education in teacher education gives the framework for this study which concerns the relation between a small group of primary school teacher students and science. My feelings can be described by adapting Antoine de Saint-Exupéry from The Little Prince “…once upon a time there was a little researcher who lived on a planet where science education was a remarkable part of life and who had the need for knowledge…”. I myself needed the knowledge of my students’ experiences. However, despite the personal interest in this study, there are also many similarities with the problems attached to science education all over the world.

In the last few years Finland has paid a lot of attention to raising the level of science instruction and knowledge, particularly within the Science and Mathematics Project called LUMA. The aim has been to enable school leavers to apply their science knowledge to everyday situations and to solving future problems. It is also important to learn the ability to critically evaluate knowledge from different points of view. Citizens also have to be able to take a justified stand to different issues and to convey their conclusions to other citizens.

The national joint programme LUMA started in 1996 and was revised in 1999 just before the beginning of this study and during my first year in the primary school teacher education. The general objective of the LUMA programme has been to raise the level of mathematical and scientific knowledge and expertise in Finland to an international level. The reason for the programme was the growing and all-pervading importance of mathematics, natural sciences and technology in societies, and hence the need both for well qualified experts in these areas and for a sound understanding of the issues that these field of studies raise by all the citizens.
1.1 The aims of the study

Teachers are recognized as being the central determining factor in successful science education. For teachers of science, including primary school teachers, beliefs about teaching and learning in general are coupled with beliefs about the nature of science and the teaching and learning of science. An understanding of current views of science is regarded as an important outcome of all science studies. Teachers have significantly contributed to the raised level of science expertise. In teaching natural sciences, the teacher’s conception of the nature of science is of utmost importance, on the one hand, and how s/he is able to convey and communicate the nature of the subject to her/his pupils, on the other.

I started this study in order to contribute to the development of Science and Technology Education which is optional minor education for primary school teacher students. The aim of this study is to explore primary school teacher students’ thoughts on science, science instruction and other relevant factors in the context of Science and Technology Education. Firstly, the interest is concerned with the explanations which students have in physics issues. These explanations are discussed on grounds of the studies and theories of knowledge types taking into account students’ science studies. My background in physics and my knowledge about physics concepts could not have been ignored, but have guided my discussion about the explanations. Secondly, the interest is directed to the experiences and thoughts which students have concerning Science and Technology Education. The main interest focuses on students’ thoughts on science and science instruction, but other factors which students are highlighting are also important. Through analysing the explanations and thoughts the students’ relations to science and science instruction are captured. Through this analysis the study seeks to clarify how primary school teacher students use language in the context of physics and how they view science.

The analysis of the primary school teacher students’ ideas about science is based on empirical case study carried out in Science and Technology Education at the University of Joensuu. In order to clarify the ideas concerning science and science instruction the students explained physics phenomena and wrote a narrative of their Science and
Technology Education. During this study the instruction was carried out for the second time in the context of society and technology.

The grounds for the research aims are derived from my personal situation as a teacher of Science and Technology and from the theoretical propositions of science education. When I taught primary school teacher students the first time during the term 1998-1999, I often got caught in situations where I noticed that students did not understand what I had said, and vice versa. Obviously, we spoke different languages. As Maturana and Varela (1992, 245) have stated I had to accept also that

"if we know that our world is necessarily the world we bring forth with others, every time we are in conflict with another human being with whom we want to remain in coexistence, we cannot affirm what for us is certain (an absolute truth) because that would negate the other person. If we want to coexist with the other person, we must see that his certainty—however undesirable it may seem to us—is as legitimate and valid as our own because, like our own, that certainty expresses his conservation of structural coupling in a domain of existence—however undesirable it may seem to us."

It has become obvious that for the coexistence I have had to understand and accept the world of my students. Through understanding and acceptance successful science instruction becomes possible.

For the educational practise, this study provides information about the primary school teacher students’ ideas in cases where they have studied sciences in the context of society and technology. Thus the role of science education and its development can be discussed in respect of the students’ ideas. For the theories and studies of science education this study seeks to capture a more coherent picture of Finnish primary school teacher students’ views of science than has been provided earlier. In the previous studies and theories in science education the teacher students’ views have been emphasized to some extent, but the studies have focused mainly on younger pupils. This study aims to clarify students’ views on science and science instruction in minor science education context relying on the role of views of science in science instruction and science studies relating to society and technology.
1.2 The current position of the science education

The view of science education as continuum, starting at pre-primary, is a basic feature of the new curriculum which was implemented in 2004 during the process of this study. The revision of the curriculum involves the re-distribution of classroom hours in the comprehensive school. The revision brings along changes to science education at the primary level. During the first four years pupils (ages 7 to 10) undertake environmental and science studies as before, but during the last two years (ages 11 to 12) at the primary level science studies are divided into biology/geography and physics/chemistry studies. These changes have put pressures on reorganising primary school science education and on changing its characteristics. Already at the beginning of this study it was obvious that the role of physics and chemistry at primary school was getting a more prominent role due to the actions of LUMA.

Non-formal learning has also an important significance in learning science. Everyone has acquired some kind of conceptions of natural phenomena before formal education. Therefore, everyday knowledge and conceptions have to be taken into account in the formal science instruction starting from the pre-school level.

The basic requirement in increasing the number of students taking advanced courses in sciences is to make these courses attractive to students. So, the key question is: Are students’ attitudes positive to the sciences? In the LUMA programme no attempt to survey the students’ attitudes to the study of science was made. The trends in students’ attitudes to science in the LUMA schools have not been recorded and compared with those in non-LUMA schools. However, pupils still don’t choose advanced science courses so often in the upper classes of the comprehensive school.

There is still a serious recruitment problem in tertiary education, which Finland shares with other countries. It causes the decline of the level of mathematical skills and knowledge among the first-year students. The corresponding problem exists in physics and chemistry. One reason for this difficult and complex problem is undoubtedly today’s mass education where more students than before take part in tertiary education which requires a lot of mathematics. Adjustments
have been made in the teaching and in the first year syllabuses to accommodate them to the changing standards and the wide spectrum of knowledge, background and interest of the incoming students.

1.3 The current position of the teacher education

Childrens’ positive attitudes to science peak at, or before, the age of 11 (Simon 2000). Two years later, at the end of the primary stage, children may have negative attitudes to science (see Sjöberg 2002, Osborne et al. 2003). Boys are more interested in physics in the contexts of ideal science, technology in society, technical applications, investigation, and design and technology. In the context of human being boys and girls indicate fundamentally equal interest. (Juuti et al. 2004) There also seems to be a trend, common to both boys and girls, to rate science as less difficult and less demanding as they are growing older. As the subject is perceived to be easier, enthusiasm for science declines (Pell and Jarvis 2001). As it appears that the trend starts towards the end of the primary years, the primary years of schooling are significant. Interest may change it’s form during the following years from universal interest to special interest (see Sievers 1999). Primary school teachers’ have thus a great influence on school children in science learning. It is obvious that the success of LUMA has to be attributed for the most part to teacher-led innovation. The motivation and initiative of individual teachers are a necessary ingredient in any progress. The major benefit to the whole school system arising from the LUMA programme was the increase in availability of in-service training for all teachers. Primary school teachers, who are responsible for Finnish primary school science teaching, were educated in this in-service training in both science disciplines, i.e., content knowledge and pedagogical issues in science.

The university teachers in the LUMA subjects are highly qualified and the curricula in LUMA subject meet the best international standards (Allen et al. 2002). For university teachers it is, of course, natural to stress the academic tradition of their subject. However, in order to increase the students’ interest in the sciences it is important in undergraduate education to stress applications and reflect more on uses in business and industry, also in primary school teacher education.
The role of the teachers, both primary school teachers (class teachers) and secondary school teachers (subject teachers), is crucial from the point of view of the recruitment of students to the sciences and preparing them well for their studies at universities and polytechnics. Consequently, the training of future teachers in extremely important, and it is also desirable to increase the status of teachers in order to attract good students to this occupation. In the teacher training programme there has been a re-assessment of the emphasis of mathematics and sciences. Different models have been developed for increasing the subject knowledge of primary school teachers and secondary school teachers during their training.

The relation and co-operation between subject departments and educational departments are essential in teacher education, both for secondary school teachers and primary school teachers. It is complicated when different departments and even different faculties are involved. The personnel does not e.g. meet in the same coffee room, and sometimes it is not even clear which department and which faculty is responsible for the content and teaching of the separate courses. Cooperation is needed for designing a course to serve the subject needs of the future primary school teachers. In subject courses for future teachers it is especially important to stress motivation and understanding by means of the history of the subject, and applications from other scientific areas, and from real life. It is also essential to discuss questions related especially to the pedagogy of the subject since this will better prepare the future teachers to understand the learning difficulties of the pupils. In the evaluation report of LUMA programme Allen et al. (2002) propose that tertiary level subject teachers of the sciences should know more about educational aspects, and that, teachers at educational departments should know more about subject aspects.

The Science and Mathematics objectives (LUMA Project) set by the Ministry of Education have stated that the universities have to design minor subjects that combine mathematics and natural sciences for primary school teacher education. As an answer to this challenge the position of natural sciences was improved in primary school teacher education at the Department of Applied Education in 1998 when the Science and Technology Education as a minor subject combination was started. The Science and Technology Education has been developed further since 2001 through a project financed by
European Union (ESR) and the Ministry of Education to meet the needs of the schools. The funding, which has been provided by the Provincial Government of East-Finland continued until July 2004. The Project utilised the research on teaching and learning science. In this education programme sciences are studied in the contexts of society and technology. Since 1998 eight to seventeen students a year have passed these studies. The entity is co-operation with the Faculties of Science and Education.

Seen from the viewpoint of teaching a subject, the teacher's knowledge of the discipline and her/his conceptions of the nature of science are essential in the teaching and learning process. Consequently, it has been recommended that the aim of science teaching should be the development of understanding of the nature of science (Lederman 1992, Abd-El-Khalick and Lederman 2000a). Another goal is the development of positive attitudes toward science. It is at least equally essential to know how the content knowledge of a subject is turned into a teachable format. The understanding of the nature of science is not adequate for teachers. Teachers’ views of the nature of teaching and learning processes are at least as important. These views have been more in focus in this century (see e.g. Kobolla et al. 2000, Tsai 2002). Also the relation between the views of the nature of science and the views of the teaching and learning are meaningful. In order to improve the science education at the primary level science education in primary school teacher education has to be taken care of. Knowing the teacher students’ experiences about Science and Technology Education and the present views of the teacher students of science, teaching science and learning science and other relevant factors are thus important. To be able to make effective choices, teachers must have an understanding of what they are attempting to convey to students. Teachers with outmoded views of the sciences do not explicitly deal with this aspect of science education in their classrooms.
2 Science education

The need for science instruction has been discussed over 50 years, and science instruction has been under revision the same period of time. The role of the teachers is accepted to be one of the most important factors for the success of science learning. As individuals and as species we develop common sense knowledge of the world around us and of ourselves by progressively differentiating various kinds of entities and aspects and relating them to each other. According to the constructivist paradigm of learning, this background knowledge of the learner has an important role in science learning. The knowledge acquired even before the formal science instruction is important for the learning of science at school. Primary school teacher students bring their existing knowledge, formed before or during their schooling, with them as they enter Science and Technology Education. From the point of view of this study, both informal and everyday learning alongside school learning are an important background for science education.

2.1 Learning outside the formal education

Informal learning and learning in everyday situations occur alongside the formal education also during the school years and the whole life. That out-of-school learning environments are not very school-like may make them therefore more welcoming to children who do not regard themselves primarily as students. But all these contexts emphasize the centrality of joining a working, learning community of peers and supportive adults. In these contexts, children shoulder a great deal of responsibility for the design of their own learning environments to make them meet their purposes and goals. Science learning can also occur in these authentic environments, where open investigations are typically used.

2.1.1 Informal learning

Once children attain the school age, it is usually assumed that schools take on the major responsibility for guiding their learning. Thus, although most people acknowledge that parents and siblings continue
to play an important role, studies of children's learning beyond the pre-school years focus primarily on learning in school settings or in school-like domains and tasks, such as mathematics, science, or reading. Besides families also the counsellors of out-of-school institutions and programmes provide opportunities and support for young people's learning. Little analysis has been devoted to the learning that occurs in the wide range of informal learning environments and programmes at the neighbourhood and community level that exist to support children's learning and development and also offer many opportunities to encounter scientific information outside the school. Informal learning environments outside the families are, for example, museums, science centres and after-school programs. (Schauble et al. 1996, 5-6.) The media informs, even in the tabloids, of major scientific issues that impinge on health, crime detection, or, increasingly at present on environmental issues. Many feature articles in the quality press discuss the implications of scientific and technological development on the life of individuals and society. Television documentary and news programmes offer also a lot of information on science issues. Background knowledge, gained both from formal classes and from life experiences, is related to understanding science messages from informal sources. (Lucas 1994, 111-118.) Programmes that serve the youth differ widely in organisation, intended audience, and function, varying from national organisations, such as the Scouts, to local grassroots organisations from 4H clubs and hobbyist societies to local sports leagues; from religious organisations to theatre groups; and from club-like activities organized around specific subject-matters to libraries and museums. (Schauble et al. 1996, 5-6.)

The goals or purposes of most informal learning contexts tend to be broader than those emphasized in traditional schooling. Strange as it may seem, informal education projects may not regard learning as their number one priority. Similarly, they do not by-and-large aim exclusively at improving classroom-oriented measures, but instead, tend to emphasize wider goals such as enculturation, development, attitude, and socialization. Thus the content knowledge is not the most important thing in the informal learning environments or in the everyday learning situations. In these environments children also learn science but often without using the scientific concepts. The prior knowledge formed for the learner is, however, an important background for the science learning at school as also in the primary school teacher education.
In many informal learning programs, social interaction, entertainment, or attitudinal agendas may be regarded as the primary concern; learning is regarded as following from these more primary outcomes. In contrast, schools more often take the opposite perspective, treating learning as the primary concern and often regarding motivation as an individual quality or as the secondary concern. Informal learning exemplifies a related view on teaching: Instead on relying on a teacher whom children are encouraged to regard as all-knowing, out-of-school contexts more often put learners into contact with an array of teachers, each one with knowledge of a particular kind of domain or skill. The implicit message is that nobody knows everything, and different kinds and levels of contributions from different participants are the norm. The emphasis is not on being told the answers by somebody who already knows them, but on finding out together how to get the job done. Rather than mastering the content for some unspecified reason that will presumably coalesce in the future, children who participate in informal learning environments are often learning to make progress toward meaningful goals. (Schauble et al. 1996, 7-9.) This view to learning is widely accepted as a good one in science instruction. The teacher does not have to know everything and s/he acts more as a guide than a deliverer of the knowledge. Learning science is not about learning facts but about learning to understand, analyse, and use the knowledge. Practises used in informal learning could be effectively applied to school as well. Many classroom researchers have found it instructive to rethink the design of classrooms in light of what works in out-of-school learning environments (Schauble et al. 1996, 9). Because the constraints of these environments are somewhat different from those that operate in schools, informal learning contexts can serve as laboratories for testing innovative approaches to learning (Schauble et al. 1996, 9).

Informal educators are more likely to consider their programmes to be catalysts of or supplements to learning, rather than having a direct effect on measurement outcomes like standardized achievement tests in science or mathematics. Thus, standard evaluation procedures that target traditional educational outcomes may very well underestimate the value of informal learning. The broader agenda of informal learning, which often focuses on changes in values, attitudes, and motivation, is difficult to assess because values and attitudes change very slowly, are diffuse and difficult to measure, and are almost certainly contributed
to and mediated by many experiences and influences in children's lives. Learning effects may emerge only over a long period of time and in circumstances quite different from those where the learning originally occurred. (Schauble et al. 1996, 19-20.)

2.1.2 Everyday learning

Families play an especially important role in screening and interpreting the meaning of settings of all kind, including those where learning occurs. Because there is typically a cyclical flow in which family members physically move from the home to the outside world at the beginning of the day, and then back again at the close of the day, the family becomes a critical locale for the discussion and interpretation of experiences that take place elsewhere. How do families and other institutions mediate and interpret learning? One important mechanism is conversation. People in different contexts talk in different ways; for example, the role and form of the talk between family members is likely to be quite different from the functions and structures of the talk that occurs at school. Because families share long histories, their conversation may seem terse and elliptical to an observer. As there is a presupposition of essential background meaning conversation need not be elaborated because it has been founded on common experiences that can be taken for granted by the participants in the conversation. In contrast, detailed explanations and presentational talk may be more characteristic for schools. The distinction between what speakers intend or mean, and what their speech actually represents is important to school learning but not in everyday communication. Like families and schools, informal learning environments may also encourage the forms of talk that have special meanings within the context, and which may have an influence on who feels herself/himself a member of the ingroup and who does not. As children spend the great majority of their time outside the classroom, so the domain of informal education is vast, not only in the amount of time children potentially spend in it, but also in the variety of activities that it includes. It is therefore essential to understand more about learning in these settings, not only because of their large, mostly uncharted influence on children, but also because such work may also provide seeds for understanding lifelong learning conducted mainly outside formal school settings that continues to be
increasingly important throughout adulthood. (Schauble et al. 1996, 21-22.) Special forms of talk that have special meaning within a certain context may also be formed after childhood. Primary school teacher students have many activities outside the science education as a peer groups. Their common histories go beyond their history in science education. They may develop forms of talk with special meanings.

There are valuable aspects of students’ knowledge and experience that originate from their informal education and everyday experiences. These aspects can help them as they move towards a professional’s view of the world. Questions and observations from fellow students or from the teacher can help students clarify what aspects in their earlier understanding are valid and in which contexts, and help identify more specifically where their earlier thinking may be flawed. (Minstrell and Stimpson 1996, 191.) Learners exhibit a confirmation bias. Seeking evidence that supports their existing ideas takes precedence over looking and accounting for disconfirming evidence. They “see” the heavier ball fall faster, partially because they believe that “heavier falls faster”. Even when students note discrepancies, they tend to discredit its source. (Minstrell and Stimpson 1996, 192.) In practical situations the social and physical contexts provide information and resources that an actor uses to establish an appropriate solution to the problem and these effective problemsolving strategies arise from knowledge constructed in practise (Roth et al. 1996). Encouraging students through classroom conversations to recognize and resolve differences between their expectations that have reflected their initial ideas and the new experiences suggest a need for a reformed conception. When students are convinced that the new observations during the learning experiences are valid, that their initial ideas and reasoning are inconsistent with the believed experiences, and the new way of thinking about the situation is understandable and seems viable, the probability for change in understanding is more likely to occur. (Minstrell and Stimpson 1996, 192.) In science education this change in understanding is considered often as a process of conceptual change, which considers learning as a process in which student reorganizes her/ his existing knowledge in order to understand concepts and processes of science more completely.

The tradition of research concerning conceptual change is rooted in developmental psychology, considering conceptual change as a cognitive function and seeing conceptual change mostly depending
on individual skills, as a part of the learning process. The conceptual change approach to learning has been under intense discussion for many years, and several different views have been presented by researchers in cognitive psychology and science education (see Havu-Nuutinen 2005). Conceptual change is essentially a process of theory change caused by increasing domain-specific knowledge. Although there are many variants of meanings given to the term conceptual change there appears to be mainstream agreement that conceptual change has to do with major restructuring of already existing knowledge (Duit 1999, 263). Conceptual change does not mean replacement of “incorrect” with “correct” conceptions, but different contextual activation of alternative representations (Vosniadou 1999, 5). Conceptual change, the process of conceptual development from a child’s prior ideas towards science concepts, has to be embedded in a bundle of what may be called “conceptual change supporting conditions”. Among these are motivation, interest and beliefs, as well as factors of the climate and power structures in the group. Science learning does not mean replacing everyday ideas totally by science ideas but to make the learner aware that in specific contexts, for particular purposes, science conceptions provide a much more fruitful framework than their own conceptions. Conceptual change is not solely to be seen as “in the head” changes of conceptions, but also as changes of the individual’s relation with the world. (Duit 1999, 265-270) Situational and cultural contexts are included in the cognitive context (Haldén 1999).

Most arguments in everyday life are non-deductive in nature and are not set in terms of a formal system. Instead, such informal arguments consist of conclusions that are supported by reasons. Moreover, the validity of non-deductive arguments is considered in terms of soundness, with soundness based on three criteria: Whether the reason is relevant to the conclusion, whether it supports the conclusion, and whether all reasons are taken into account that could support the contradiction of the conclusion. Thus, such arguments are not valid or invalid, but they are regarded as relatively sound or unsound. Informal reasoning may be regarded as the processes of reasoning that occur when individuals generate a non-deductive argument and/or evaluate its soundness. (Voss, 1989, 220.)

Pupils in our schools live within a community that has its own, everyday or common sense ways of talking and thinking about the
events and phenomena which are of interest to scientists. The case of air pressure describes the ways of talking. The action of drinking orange through a straw is described in everyday situations in terms of “sucking”; for example, children from an early age are able to respond to parents’ requests to “suck quietly” as they drink through a straw. For a parent and a child, little difficulty is involved in establishing a shared understanding of what is meant, as a child is immersed in this kind of talk from birth. (Leach and Scott 2000, 42.) Also when a child explains light to be rebounded from the wall teachers and scientists understand that the child means reflection.

Folk theories, the term which Bereiter (2002, 7) uses, means common sense, just the way things are. Folk theories generally have the aura of certainty rooted in direct experience. That the Sun rises in the east and moves across the sky once seemed to be given directly by experience, to involve no conjecture or interpretation whatever, whereas what happens to the Sun between the times it disappears in the west and reappears in the east is conjectural. To the modern mind, however, it is evident that the daytime cycle is also a matter of interpretation, even if not in quite the same way as what happens to the Sun at night, and that interpreting it the way folk astronomy is doing, gets one off onto a wrong path in understanding the cosmos. Similarly, folk mechanics is based on the unquestioned observation that objects set in motion gradually lose their initial impetus and come to rest. From the standpoint of Newtonian mechanics, the loss of impetus, far from being an uncontaminated observation, is an inference that has to be questioned for physics to progress. According to one usage of folk theories people believe in them in the absence of scientific theories. According to this usage, folk theories are to be found mainly among primitive peoples and among children who have not yet been introduced to science. Bereiter sees, however, that folk theories are whatever theories or conceptual frameworks which people pick up from popular culture and use in their daily life efforts to make sense of events and to plan their actions. We all acquire folk theories and are apt to go on using them until we get deep enough into an endeavour that requires specialized knowledge from us.

However, potential difficulties in establishing shared understandings arise when a child revisits these familiar events in science lessons at school. In the classroom the teacher faces the challenge of introducing students
to the scientific ways of interpreting and explaining phenomena, which the students are already thinking about in their own everyday ways. This same situation emerges again when primary school teacher students enter Science and Technology Education. As a teacher my way of speaking about the natural phenomena seems to be quite different from that of my students'. What they have learned during their school time, or even before that and in everyday situations has influenced their way of explaining physics and experiencing science. But do they still have another way of experiencing science, a way typical for the primary school teacher students?

2.2 Science instruction

Besides informal learning and everyday learning primary school teacher students carry their whole school history with them. They have been “targets” of school teaching for twelve years. During that time they have studied sciences at least for the first nine years. Thus school science instruction has a significant role to their views of science. School science instruction uses its own language which approaches scientific language. The culture of schools is, however, different from the one of scientific cultures. This has been one of the topics in the discussion of science instruction which has undergone wide changes during the last decades.

2.2.1 Change in the science instruction

As the general view of instruction has changed, the conceptions of science instruction have changed, too. Education, both formal and informal, can be dramatically improved – if we can make the study of education more like the study of science, i.e., guided by theory, principles, and productive methodologies, as Joseph D. Novak has stated. A search is being carried out for new and more powerful paradigms for guiding educational research and practice.

For the first half of the 19th century, psychology was dominated by behaviourist analyses that sought laws of learning of great generality. These laws were thought to be species-, age-, and content-independent. Learning was viewed as an individual, primarily passive
activity involving the formation of simple associations governed by external reinforcements. Complex behaviours were seen as involving the extension and combination of those associations. More recently, theorists have emphasized the active, reflective, and social nature of learning. Following the "cognitive revolution", the model of the human learner, including the child, has been transformed. Learners came to be viewed as active constructors, rather than passive recipients of knowledge. Learners were imbued with powers of introspection; they were granted knowledge and feelings about learning, sometimes even control of it, metacognition. (see e.g. Mintzes and Wandersee 1998.)

The development of cognitive sciences has had great influence on science education. Among the most significant studies done by cognitive scientists are attempts to explore and compare the idiosyncratic knowledge structures of novices and experts in scientific domains. The research on the structure and use of knowledge in natural sciences have shown that experts tend to excel singularly in their domain of knowledge and that transfer to other domains is quite limited in most instances; experts tend to see large meaningful patterns in their knowledge domain and this enables them to solve problems more quickly; experts generally possess a stronger hierarchical, cohesive framework of related concepts and they use those concepts at a "deeper", more principled level; and experts typically have strong "metacognitive" or self-monitoring skills that enable them to diagnose and remedy errors in comprehension. (Mintzes and Wandersee 1998, 43; metacognition review see e.g. Lehteli 2001.) Discontinuities in idealized school-like knowledge and that used in everyday life outside schools lead to sentiments that science requires to have a special rationality, early abandonment of science, and ultimately differences in the discursive practices of scientists and those of the "just plain folks" who institute the power of the former. In this way, schools contribute to the myth of scientists as members of a special breed. Thus schools are not only gatekeepers that select future generations of scientists but they also close the door on educating scientifically literate citizens able to deconstruct the practices of science. (Roth et al. 1996.)

Over a period of about 25 years researchers have amassed a mountain of information concerning students' "alternative conceptions" of natural phenomena in biology, chemistry, physics, and the earth and planetary
sciences (see Duit 2004). This knowledge combined with disciplinary, metacognitive, and domain-specific pedagogical knowledge has the potential to transform the classroom from a "training centre" to a place where understanding and conceptual change are encouraged (Mintzes and Wandersee 1998, 45; conceptual change review see e.g. Havu 2000, Havu-Nuutinen 2005). This view is embodied in a theoretical synthesis that Novak (1993) has called human constructivism. This is a view of meaning-making that encompasses both a theory of learning and an epistemology of knowledge (see e.g. Sormunen 2004) building. The three important assertions of human constructivism are: human beings are meaning makers, the goal of education is the construction of shared meanings and shared meanings may be facilitated by the active intervention of well-prepared teachers. Human constructivist period began with the publication of Ausubel, Novak, and Hanesian in 1978 and has continued to the present (Mintzes and Wandersee 1998, 60).

Human constructivists assert that the cognitive processes resulting in the extraordinary creative work of Nobel laureates are essentially the same as those of a student who is wrestling with her or his first exposure. In both cases individuals construct meanings by forming connections between new concepts and those that are part of an existing framework of prior knowledge. It is this meaning-making mechanism, embodied in a complex set of language symbol systems that is an essential adaptation of the human species. No human beings, scientists included, construct precisely the same meanings even when presented with identical objects or events. As a result, our understanding of “structure” and how students might come to know it must be revised. This, in turn, demands a reconsideration of the goals of education and the methods teachers use in their interactions with students. (Mintzes and Wandersee 1998, 46-49.)

2.2.2 Instruction practices

Among the novel intervention strategies that seem to have great potential and promise to substantially impact the way science teachers carry out their professional responsibilities are the use of graphic organizers, metacognitive tools, confrontation techniques, and targeted analogies. To facilitate understanding and conceptual change also the use of
microcomputers and hypermedia technologies, as well as the use of small groups, historical vignettes, and conversations about science are seen to have potential value. (Mintzes and Wadersee 1998, 51.)

**Pedagogical approaches**

Like the change in theoretical framework looking at the historical development of didactics three different basic didactic approaches stand out: prescriptive; rationalistic; and reflective (Laursen 1994, 126). The prescriptive theories are the classical theories of teaching and they give concrete and precise guidelines on how to teach and how to plan lessons. They are not based on an analysis of the actual teaching practices but focus on ideals. They totally dominated educational theory until the beginning of the last century.

Rationalistic theories first appeared during the early decades of the last century and they suggested abstract and procedural guidelines on how to teach and primarily on how to plan lessons. Like the prescriptive theories they are not based on an analysis of the actual teaching practices but instead they focus on rationalistic principles and theories of learning. The Behaviourist influence tried to transform theories of learning into methods for efficient teaching. This endeavour has, to some degree, been successful but the Behaviourist theories are still limited to teaching methods – they say little about aims and content of instruction. The rationalistic approach does not respect the fundamental realities of teaching – that is the institutionalised and routinized character of teaching and the plurality of rationalities in teacher thinking. (Laursen 1994, 126-128.)

Reflective theories can be traced back to John Dewey and have been dominant during the last decades. They provide very abstract guidelines for teaching. These theories are the only ones based on an analysis of the teaching practices. Reflective theories of teaching must simply start with a critical analysis of the actual routinized practices of teaching going on in schools. The relationship between the institutional framework and the teaching practices must be emphasized because the reform of institutional settings is often a prerequisite to the reform and development of teaching practices. (Laursen 1994, 126-134.)

Human constructivists generally discourage teaching strategies that focus on the passive "reception" of knowledge. Lecturing with verbatim note-taking, film-watching, "cookbook"-style laboratory exercises,
algorithmic approaches to “problem-solving”, and independent work that stresses repetive “drill” are examples of techniques that too often encourage rote learning. Instead, human constructivists favour approaches that demand active participation, intensive interaction, and thoughtful reflection. These activities may take the form of small, cooperative group work, debates, one-to-one conversations, demonstrations, or laboratories that introduce and attempt to resolve conceptual conflict, interactive technologies, and whole-class activities that provide context and encourage meaning-making, such as historical vignettes and the creative use of analogies, metaphors, and story-telling. They also think that students need to learn how to learn; for most individuals, this is not a skill that “comes naturally”. The use of concept maps and other metacognitive strategies can help students to monitor and control their own learning. They discourage assessment strategies like multiple-choice/true-false, fill-in and similar “objective” tests in favour of concept maps, essays, portfolios, verbal reports, and other methods that recognize, reward, and encourage meaningful learning. (Mintzes and Wandersee 1998, 52-53.)

Traditional objectives for schooling in science have emphasized the transmission of content by means of lectures. Reform in science education has increasingly focused on laboratory activities as a means for learning science in a more meaningful way. These approaches were based on the assumption that the structure of nature revealed itself to students as they engaged in hands-on activities, leading to the notion of discovery learning. In discovery learning the learner must arrange a given array of information, integrate it with her/his existing knowledge, and reorganize or transform the integrated combination in such a way as to generate a desired end product, typically a new concept or proposition (Ausubel and Robinson 1969, 44). The absence of better understandings, despite these approaches, is explained suggesting that the structure of the natural world or the nature of tools cannot be understood apart from the human practices in which they are relevant. By engaging students in traditional laboratory activities, students appear to learn procedures for following instructions rather than gaining scientific understandings. Many leading educational theorists have attributed the shortcomings of traditional science teaching to the underlying realist epistemology and have proposed developing new teaching/learning environments compatible with constructivist
and social-constructivist views of knowing and learning. (see Roth et al. 1996; Tobin 1994.) For their part children appear to like the co-operative practical hands-on aspects of science where they choose an equipment and find out what will happen (Pell and Jarvis 2001, children from 5 to 11; Parkinson et al. 1998, children from 11 to 14). However, children are not so keen on working out how to set up an investigation or finding out why the results occur. Students are, on the other hand, observed actively to engage in science, using a hands-on inquiry-based approach and this pedagogical approach has made science interesting for students (Gibson and Chase 2002).

Educators usually aim to teach competencies that have wide applicability. Rather than trying to impart volumes of specific knowledge, as it is often argued, instruction should cultivate general abilities that facilitate learning throughout life and in different settings. Educational research has long addressed this question under the rubric of transfer. Recently considerable evidence from both cognitive studies of learning and developmental studies of cognitive self-management points to a feature of successful learning that goes beyond specific knowledge. Successful learners tend to elaborate and develop self-explanations that extend the information in texts or other instructional material. An important finding is the strong difference among learners in their tendency to monitor their own understanding as they work. Better learners seem to attend intensively and assess properly their own state of understanding, perhaps as a prelude to their elaborate activity. Differences in individuals’ self-monitoring and tendency to elaborate have been widely noted as distinguishing weaker from stronger readers and also people with better knowledge from those with lesser knowledge on the topic being studied. These disparities have given rise to the concept of metacognition. Substantial work now suggests that knowledge about cognitive processes is probably less important than self-monitoring of those processes. The habit of meaning-making, the tendency to elaborate and seek relationships has emerged in recent discussions as a major candidate for explaining the strong tendency for good learners in one domain to be good in others as well. Disposition to elaborate or intention to learn represents an alternative in looking for generalities and transfer in basic processes or in packages of knowledge that have wide applicability. From intentional efforts to find links among elements of knowledge, to develop explanations and
justifications, and to raise questions, lead to observed generality and transfer to learning. (Resnick 1989, 8-9.)

**Nature of science and scientific knowledge in instruction practices**

Human constructivists take a moderate position on the nature of science. On the one hand, they find the views of classical “logical-positivists” intellectually indefensible; on the other, they think that many constructivists have created a relativistic mind-world that is ultimately self-defeating. Instead they prefer a view of science that acknowledges an external and knowable world, but depends critically on an intellectually demanding struggle to construct heuristically powerful explanations through extended periods of interaction with objects, events, and other people.

From the human constructivists’ perspective, knowledge is not a simple transcription of real world objects or events that can be faithfully communicated either from direct observation of nature itself or from one person to another. Instead, knowledge is an idiosyncratic, hierarchically organized framework of interrelated concepts that has been created by scientists and science students over time. The building of a unique conceptual framework is an active process that requires connecting consciously new knowledge to existing knowledge and testing it against one’s perceptions of the real world objects and events and the knowledge constructed by others. The unique framework so constructed is substantially overlapping: it is the overlapping nature of “core” knowledge in scientific disciplines that makes education possible. The most important knowledge that individuals can have is well-differentiated, highly integrated, domain-specific concepts; it is the structure of our conceptual frameworks that largely determines our success in using existing knowledge and the nature and quality of our subsequent learning experiences. (Mintzes and Wandersee 1998, 52.)

Science and teaching are social processes dependent on attitudes, values, and social interests, not just on knowledge and skills. Science education perpetuates a view of science as objective, authoritative, and exclusive in the sense that it is presented in opposition to common sense and as comprehensible only to those possessing special talents. (Warren and Rosebery 1996, 97.) Scientists transform their observations into findings through argumentation and persuasion,
not through measurement and discovery. The activity of scientists within a laboratory is seen as a constant struggle for the generation and acceptance of fact-like statements. Their accounts detail how the factual statements are constructed or reconstructed in laboratories through the superimposition of several statements or documents in such a way that all the statements are seen to relate to something outside of, or beyond, the reader’s or author’s subjectivity. These documents (e.g., histograms, spectra, peaks, recorded numbers, etc.) are obtained from what they call “inscription devices” (e.g., bioassays, spectrometers, etc.) generated within the laboratory or from papers written by investigators outside the laboratory; they are, in short, the means by which scientists convince others within their community to take up their claims, to pass them along, to make them more or less of a fact. In this culture, the showing of things that are not present or not visible is inseparable from the telling. (Warren and Rosebery 1996, 113-114.) To follow this model classroom discourse can be organized around student argumentation that brings into focus an alternative view of science and science education as socially and culturally constituted, meaning-making activities (Warren and Rosebery 1996, 97). A focus on dialogism may open new perspectives on what it means to say that learning is situated-constituted in and through the activity, context, and culture in which it is developed and used (Warren and Rosebery 1996, 120).

Many science teachers, who are themselves products of a university system which values scientific knowledge more than the history and philosophy of science, show the lack of understanding of the nature of scientific knowledge. Perhaps an analogous observation would be that great players of a sport seldom make the best coaches for it – they “do what they do” almost implicitly (Wandersee and Roach 1998, 284). However, there is a relationship between how scientific communities and science students increasingly construct more powerful models of how the world works.

Many existing curriculum materials that address the nature of science misrepresent it as inherently positivistic; this essence is sustained by teaching practices such as “cookbook” laboratory activities and finding the predetermined correct answer to a so-called “experimental” activity. Students who follow the recipe-like “scientific method” of stating the problem, formulating a hypothesis, doing a controlled experiment,
confirming or rejecting the hypothesis, and drawing a valid conclusion are rewarded with first-place ribbons – while students who perform exploratory or naturalistic, observation-based research usually go home empty-handed. The imagination of research design and the excitement of discovery are also diminished by science teachers who offer mindless, step-by-step, failure-free laboratory activities intended to verify the teacher’s lectures. No wonder students are opting out of elective science courses or jettisoning their intended science majors at their earliest opportunity. Students must be provided insights into how people, such as Galilei and Einstein, used intuition and imaginative processes to help them make breakthroughs in science. In so doing, students need to have some understanding of the cultural and political temperaments of their time in order to fully understand that science is an integral part of society. (Wandersee and Roach 1998, 285-286.)

In recent years there has been a surge of interest in classroom activity, in which students learn through design, invention, and construction to model scientific work and thus understand the nature of science. Design activities provide rich opportunities for learning. There are many reasons for this interest in design-based learning: engage students as active participants, encourage reflection and discussion, encourage a pluralistic epistemology, be interdisciplinary, provide a sense of authenticity, facilitate personal connections and promote a sense of audience. Unfortunately, most classroom-based design projects do not correspond to these ideals. In many cases, educators propose highly restrictive design tasks or even cookbook-style recipes for constructing particular artefacts. Students are given little opportunity to redefine and restructure the tasks. In such cases, students are less likely to make personal connections with the design activities or with the domains of knowledge underlying the activities. (Resnick 1996, 162-163.)

A computational construction kit LEGO/Logo can be used in constructional design, for example. This construction set allows children or students to construct buildings and machines. In addition, children and students are able to program and control the things they have built. After building a model house, a child should be able to add lights to the house and to program the lights to turn on and off at particular times. The idea is to combine several different design activities. LEGO/Logo includes new types of LEGO blocks for building machines and new types of “Logo blocks” for building programs. In
addition to the familiar LEGO building bricks, there are new LEGO pieces such as gears, pulleys, wheels, motors, lights, and sensors. There are optosensors that detect changes in the level of light and touch sensors that detect pressure. Just as students can build increasingly complex structures and machines by snapping together LEGO bricks, they can build increasingly complex computer programs by “snapping together” Logo commands. (Resnick 1996, 164-165; Enkenberg 1989; Järvelä 1996)

**Effective teaching**

Good teachers do things well and know conceptually why they do them well – they have an explanation for what their practices are grounded on. Good teachers also know what goals they plan to achieve and push students toward into realizing those goals. These teachers focus on learning – on students’ learning. Within classrooms two paradigms – teachers’ approach to the way students are to “engage” in content material – dominate: one instructional, the other learning (Table 1). The instructional paradigm focuses on what the teacher does in the classroom, and the instructional-paradigm teacher is one who views the teaching act as relatively remote from the learner. Learning-paradigm teachers (Table 1) focus on whether and how students learn. Their focus is on student’s learning, not on the teacher’s behaviour. (Ornstein, 2000, 5-7.)

Most teachers and a majority of administrators focus on the instructional paradigm. That is not their espoused theory, but it emerges as their theory-in-use. They and the larger community they serve (parents and a variety of significant others) want to see students look busy and get their work done – indeed, for years many state legislators have worried more about the hours allocated for instruction than about the learning outcomes expected from students. Instructional – paradigm teachers focus on the tasks of teaching and keeping students focused on specific activities such as dittos or workbook pages, or the “odd-numbered problems”. The far fewer teachers who embrace the learning paradigm function in a very different way relative to their role as a facilitator of learning. They are constantly “reading” the students to determine how to create a better atmosphere for student growth. Learning – paradigm teachers get outside themselves and get inside the minds of the students: How do they learn? How do they construct
knowledge? How do they make sense of the world? How can I, as a teacher, participate in the learning process with my students? In short, these teachers connect with their students. (Ornstein 2000, 7.)

Table 1. Two paradigms - teachers' approaches to instruction - within classrooms (Ornstein 2000, 7).

<table>
<thead>
<tr>
<th>The instructional Paradigm</th>
<th>The learning Paradigm</th>
</tr>
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<tbody>
<tr>
<td>Mission and purposes</td>
<td></td>
</tr>
<tr>
<td>• Provide/deliver instruction</td>
<td>• Produce learning</td>
</tr>
<tr>
<td>• Transfer knowledge from faculty to students</td>
<td>• Elicit student discovery and construction of knowledge</td>
</tr>
<tr>
<td>• Offer courses and programs</td>
<td>• Create powerful learning environments</td>
</tr>
<tr>
<td>• Improve the quality of instruction</td>
<td>• Improve the quality of learning</td>
</tr>
<tr>
<td>• Achieve access for diverse students</td>
<td>• Achieve success for diverse students</td>
</tr>
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<table>
<thead>
<tr>
<th>Teaching/Learning Structures</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>• Atomistic; parts prior to whole</td>
<td>• Holistic; whole prior to parts</td>
</tr>
<tr>
<td>• Time held constant, learning varies</td>
<td>• Learning held constant, time varies</td>
</tr>
<tr>
<td>• One teacher, one classroom</td>
<td>• Whatever learning experience works</td>
</tr>
<tr>
<td>• Covering material</td>
<td>• Specified learning results</td>
</tr>
<tr>
<td>• Private assessment</td>
<td>• Public assessment</td>
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One of the most important things a teacher can do in the classroom, regardless of subject or grade level, is to make students aware of their own metacognitive processes – to teach students to examine what they are thinking about, to make distinctions and comparisons, to see errors in what they are thinking about and how they are thinking about it, and to make self-corrections. Some argue that critical thinking is a form of intelligence that can be taught. Critical thinking is more complex than ordinary thinking and is based on standards of objectivity, utility, or consistency. Teachers should help students change from guessing to estimating, from preferring to evaluating, from grouping to classifying, from believing to assuming, from basic inferring to logical inferring, from associating concepts to grasping principles, from noting relationships to noting relationships among relationships, from supposing to hypothesizing, from offering opinions without reasons to offering opinions with reasons, and from making judgments without criteria to making judgments with criteria. (Ornstein 2000, 17-20.)
Skills can also be fostered in different ways. Three categories of components of critical thinking can be pointed out: meta-components (higher order mental processes used for planning, monitoring, and evaluating what the individual is doing), performance components (the actual steps the individual takes), and knowledge-acquisition components (processes used to relate old material to new material and to apply new material). Critical thinkers tend to be open minded, take a position (or change a position) when the evidence calls for it, take into account the entire situation, seek information, seek precision in information, deal in an orderly manner with parts of a complex whole, look for options, search for reasons, seek a clear statement of the issue, keep the original problem in mind, use credible sources, remain relevant to the point, and be sensitive to the feelings and knowledge level of others. The best way to teach thoughts is to ask students to explain their thinking, to require them to support their answers with evidence, and to ask them thought-provoking questions. Part of the reason critical thinking is so important is that a teacher cannot teach students everything they need to know. (Ornstein 2000, 20-21.)

In reception learning, the entire content of what is to be learned is presented to the learner in its final form, and in discovery learning the principal content of what is to be learned is not given in its final form but must be discovered by the learner (Ausubel and Robinson 1969, 43). In inquiry-discovery techniques of teaching, questions, answers, solutions, and information are devised for and derived by the students. The techniques can be adapted to students of all ages. The teachers’ behaviours that are considered most effective in fostering inquiry-discovery skills among students in science courses are: accepts students’ ideas, develops students’ interests and creative potential, recognizes students’ personal limitations, provides a stimulating and approving environment, sets high expectations for students, views learning beyond classroom boundaries, develops effective communication skills, wants students to apply knowledge, puts more emphasis on the process of learning than on the outcomes, stimulates in-depth learning of a subject, allows students to pursue activities, thus students have a sense of closure, creates a sense of ownership in students’ learning, permits students’ choices and decisions concerning classroom activities, designs learning experiences around students’ life experiences, needs, and interests, encourages risk-taking and a questioning attitude.
reduces classroom anxiety, encourages divergent thinking and new ideas, encourages students’ frequent self-evaluation, provides sufficient structure for students to understand goals, rules, and routines without stifling creative behaviour, provides students with an awareness of the interrelationships of science, technology, and social science. These behaviours encourage students to “mess around”, to explore, to experiment, to appreciate new techniques, to respect differing ideas, to make mistakes and to learn from them. Students taught by teachers who use these behaviours tend to be more creative, more innovative, and more at ease with themselves as well as their peers and teachers compared to students taught by teachers who use more conventional methods of teaching. Learning-paradigm teachers learn to accept and encourage the inquiring and divergent minds, minds that question and challenge common thinking and are willing to avoid the ordinary and think of the unusual. (Ornstein 2000, 26-28.)

Learners who develop well-organized knowledge structures are meaningful learners, but those who are learning primarily by rote are not developing these structures and/or their knowledge includes many misconceptions. The reception/discovery and meaningful/rote dimensions do not describe simple dichotomies but instead are more of the nature of continua. Any learning that occurs is not simply either meaningful or rote: it is, instead, more or less meaningful or more or less rote. (Ausubel and Robinson 1969, 44-45.) While experience with “hands-on experience” is important, it is also important to carefully clarify the meanings of words (or concept labels) and prepositional statements. Much of this could be done by didactic or reception instruction, provided that it is integrated with appropriate experience. Making the distinction between learning approach and instructional approach is important. With regard to instruction, either reception instruction or inquiry (or discovery) approaches can be very rote or very meaningful learning experiences (Figure 1, Novak 1998, 11).
Figure 1. The rote-meaningful learning continuum is distinct from the reception-discovery continuum for instruction (Novak 1998, 11).

Science-Technology-Society education was born in Britain, United States and Australia and is one of the reflective approaches toward more meaningful learning, autonomous discovery/inquiry instruction and understanding the nature of science. Science-Technology-Society orientation has been on the background in planning the Science and Technology Education which forms the context of this study.

2.3 Science-Technology-Society education

By the end of the 19th century there was a universal education, but there was very little science on the curricula. The question that the early 20th century had to face was whether the public – society as a whole – had any role to play in science, and whether science as a system of thinking was sufficient in itself to give an ordinary citizen with no intention of becoming an academic scientists, something of the value that was to be included in her/his education. Science today differs dramatically
from the “science” of 1660 and 1860. Each stage in the evolution of science has been shaped and reshaped by social forces, both from outside and inside science. The social forces of the 17th century gave birth to the institutionalisation of science (called natural philosophy at that time). The social forces of the 19th century precipitated the professionalization of science. And finally, the social forces of the 20th century mounted the socialization of science. Different incentives for a new kind of science education came also indirectly from an influential report by a group of the world’s top intellectuals, economists, and business people called The Club of Rome. (Solomon 1994a, 3-6; Aikenhead 1994, 11-17.)

Although it would be grossly misleading to single out any one date that marked a culmination of the post-Sputnik reform effort in United States, July 20, 1969, the day the world watched Neil Armstrong set foot on the moon, suggests itself as a tangible and widely heralded turning point. Although federal funding for NASA and other “big science” projects continued at significant levels for many years to come, money spent on science education at the elementary and secondary school levels began to dwindle rapidly thereafter. Public attention shifted in the ensuing years from science and technology to domestic issues, especially those laden with social and political significance. (Mintzes and Wandersee 1998, 41.) Science-Technology-Society (STS) education is a reflective approach to answer these new challenges set for the science education.

2.3.1 Background of STS education

Mainstream British science has traditionally resisted both political and practical technology. For years it looked only to the Royal Society for leadership. Robert Hooke, for example, was from lower class origins and spent much of his early scientific career making air pumps and other mechanical devices for more upper crust scientists, such as Robert Boyle, to be used in demonstrations for the Royal Society. In the 17th century the inspired engineers of steam power had little education in science. Some of the innovative engineers, such as the Cornishman Trevithic, could not even sign their names on patent forms. The abstract theory of thermodynamics arose from the mathematics of a French savant, Sadi Carnot, who considered the operation of an
idealized engine more than a century after the real steam engines had been set to work. As long as science remained a semi aristocratic top-down pursuit, which it mainly did during Newton’s time and for the two centuries following, it did not need to consider the cause of the common citizen. Science was a reflection of the contemporary culture, just as the community of scientists today reflects our own more democratic contemporary culture. (Solomon 1994a, 4-5.)

Top-down science also held back other kinds of progress. The Industrial Revolution produced pollution on a scale we can hardly imagine today, and there was no one to use scientific knowledge to control it. The new chemical industry made alkalis such as sodium and potassium hydroxide by profitable new methods, and in the process, huge quantities of hydrochloric acid gas was released, making an acid rain of pH 2. There was almost no comment on social issues from the learned scientists, most of whom, had not contributed to the new mechanical and chemical progress. Consequently, there was no resource for those unlearned in science who had to operate the new machines or live in the areas devastated by the acid rain or strong acid. Also books like Rachel Carson’s Silent Spring (1962) drew attention to the environmental effects of new technologies. Chemical and nuclear wastes produced pollution that most scientists and industrialists chose to ignore. There was little or no legislation to provide the ordinary citizen with access to information about these science- and technology-based hazards. Clearly, there was not enough information. People would have needed an understanding of science if they were to express an opinion on the quality of their environment. This was the first call for a science education that would be appropriate for the ordinary citizen. The energy crisis of 1973-1974 raised the price of petroleum so that the cost at the gasoline pump quadrupled in a single year. These events stimulated a series of pessimistic television programs of a type that became known as the “doomsday syndrome”. This was noteworthy because the new type of public or citizen science was using the medium of television as its “text” far more than it was using schoolbooks. (Solomon 1994a, 6.)

The scientists were still keen on bringing their knowledge to bear on solving world’s problems. In the 1960s, a group of American plant breeders working in Mexico had developed strains of new “miracle Grains” - wheat and rice – that launched the Green Revolution. This
was designed to enable the Third World to feed itself and at first it seemed to be a remarkable success. Some scientists were optimistic about solving other problems, too. They focused attention on the new technologies of alternative and nuclear power. They placed the problems of the developing world on the agenda of science. If science and its technology were to solve these problems, as some seemed to believe, then this could be a new area of activity for science. At the very least it provided an attractive new way of teaching the traditional concepts of science through their applications. (Solomon 1994a, 6-7.) In Britain the first STS approach was used with 17 to 19-year-olds in public school. The debate over the global "Limits to Growth" was carried out in schools for some privileges. Problem solving in a Third World context became soon a popular activity in science lessons, perhaps because of the high moral implications of "doing good" for the unfortunate in less developed countries. This early form of STS education separated from the later STS courses. It was based on the premise that the traditional scientific thinking could solve all the social problems in the STS arena. Teachers were enthusiasts for scientific thinking in a way that made them very suspicious of environmental movements or any other "bottom-up" pressure groups that did not base their case on respect for traditional "valid" science. The proponents of the earliest STS courses in Britain taught that science was about "facts" and that its history showed a trail of unmitigated progress and triumphs. In educational terms, this scientism tended to trivialize STS, but fitted in well the high academic status of the schools involved in the educational initiative. This was not citizen-science but top-down remedies from the scientific elite on behalf of the less fortunate. In many cases this STS approach remained firmly in the tradition of establishment science, even though the texts now included such issues as renewable resources, industrial management and nuclear power. Similar circumstances were at the beginning in the United States. (Solomon 1994a, 6-8; see also Miller 2000; and Aikenhead 2000.)

High achievements in science will only come about if the general population wants and values it (Solomon 1994a, 8). If the absence of scientific knowledge prevents ordinary people from thinking and acting on issues which they care deeply about then science education has failed. School science education, according to the new agenda of STS, had a duty to empower the action of future citizens. STS with
its emphasis on social responsibility was needed inside the curriculum to complement the more traditional approach to science education. The new STS teaching was very different from the old way of teaching and it made sense. Traditional contemplative science had not only removed itself from the worlds of action and citizenship, it had also claimed the high moral ground for abstract thinking. Indeed, some of the old advocates of science in the curriculum had claimed that the rigors of logical thought and the discipline of experimental verdict could produce the best training for a good moral life. All belief in the moral neutrality of science should have vaporized in the searing heat of the Hiroshima explosion. Science and scientists have responsibilities towards society and in STS courses those responsibilities would be encountered in the classroom. (Solomon 1994a, 10.)

Today’s children - the next generation – will undoubtedly live in a significantly more scientific and technological culture. The rapid expansion of the computer promises to relieve human beings of an ever larger share of routine and repetitious work. The economic need for and value of a scientifically literate populace are well known. The industrial challenges of the 21st century will be the manufacture of microcomputer chips, genetically-engineered products, and new products yet to be invented. In this kind of economy, a basic understanding of science and technology will be the starting point for the development of the additional professional and technical skills needed to be competitive in an era of intense international economic competition. Parallel to the need for a more scientifically literate workforce, the economy of the 21st century will need a higher proportion of scientifically literate consumers. (Miller 2000, 21-22.)

During the past years young people all over the world have showed interest in biology and environmental sciences, but not in physics and chemistry. This situation is known also in Finland. Except that Finnish pupils’ performances in TIMSS 1999 were at good average level (Kupari et al. 2001) these subjects are not seen as interesting topics. The results in the international tests have also lead thoughts to the future of science and technology education. The strengths of Finnish pupils have been in the skills to acquire scientific knowledge and in the knowledge in chemistry. The weaknesses of the pupils have been in the environmental and natural resources questions as well as in the physics knowledge. Also in a Swedish study with pupils about the same
age, green house effect for example was understood poorly (Andersson 2001). PISA 2000 research concentrated in different content domains from TIMSS. The important issues in PISA were also process skills rather than knowledge in different domains. Finnish pupils did well in PISA 2000 (Reinkainen 2002). They were in the third place after Korea and Japan. In the latest PISA 2003 research Finnish pupils were the best ones (www.minedu.fi). Lots of resources have been given for the development of science education. One alternative in making sciences more interesting and more understandable also for the future pupils, is the use of the STS approach in science education.

2.3.2 Multiplicity of approaches to STS

There are six different approaches to STS education: application, vocational, transdisciplinary, historical, nature of science, and sociological approaches (Ziman 1994, 25-28). These approaches are not contradictory but complementary. Each approach tries to introduce the student to some particular aspect of science in its social context, and thus to complement and extend conventional science education in that particular direction. STS education has not developed holistically. The fundamental purposes of STS education are genuinely and properly diverse and incoherent. (Ziman 1994, 22).

The most natural way to extend “valid” science is to extend it towards its technological and other practical applications. The principal justification for the support of basic research by society is its potential utility. Pedagogically, this is a relatively open and easy path to follow. There is a long tradition in illustrating scientific concepts by their applications. There are innumerable possible starting points, ranging from everyday matters of the weather and cooking to the sophisticated enchantments of chemical industry and space transport. In this approach people ought to know something of those aspects of life that science has affected. It is a quick stride from science to technology but it usually fails to extend to the society.

Vocational approach to STS education turns out to be better at the university than at the school level. Students are studying scientific and technological subjects as preparation for careers. The rationale of such an approach is clear. Although courses such as these are often unconnected with other initiatives for STS education, they penetrate
deeply into the society, and raise critical questions about the social role of science and technology.

One of the major movements for the reform in science education in recent years has been to break down the barriers between disciplines. Although transdisciplinarity as such is not usually regarded as one of the major routes into STS education, it has close links with it. The goal of integrating the sciences, and presenting scientific knowledge as a unity, is clearly justified from a philosophical point of view. The holistic conception of science is surely essential and it is the basic principle for the STS education. Transdisciplinarity as a central pedagogic principle thus provides one potential approach to STS education. It presents a correct account of the nature of scientific knowledge in terms of its actual content.

The history of science is not just a fascinating story of human enterprise. It is an indispensable dimension for any understanding of the nature of science itself. STS education must encompass this dimension. It must show that science and technology grow and change in association with the societies in which they are embedded. The historical approach, by showing how things got the way they are, is one of the most compelling ways of explaining the present state and also of laying out the grounds for discussion of how it might be changing. From a narrower pedagogical view, the history of science and technology provides excellent case studies of processes still at work in contemporary society.

One of the principal objectives of STS education must be to give an account of the nature of science. Science should be presented more or less as a coherent body of knowledge, organised logically around theoretical principles and validated by observation and experiment. Philosophy of science is a very difficult subject of byzantine complexity and unplumbed depth.

The very notion of teaching about science, technology, and society clearly suggests a sociological approach. It calls directly for teaching about science and technology as social institutions that are internally organised to produce knowledge and know-how, and externally linked to and embedded in society at large. The sociological approach opens up into a wide area of study. It shows that individuals are trained in and achieve scientific significance through their institutions.
The principal goal of many exponents of STS education is to offer enlightenment on the great problems of our times, problems, such as the destruction of the natural environment, overpopulation, endemic disease, poverty, and war. These problems are so interrelated that they are often described as components of a single complex world problematique. It is widely argued that the grave situation in which humanity now finds itself is due to the misapplication of science and technology in the past, and that the only hope for the future to put matters right is to use science wisely. It is not necessary to buy the whole of this argument to appreciate its force as a rationale for general STS awareness. It also suggests a major line of approach to STS education. All that is required is to teach straightforwardly about various aspects of the problematique, latching onto the concern that those various aspects arouse among thoughtful students. (Ziman 1994, 30.)

The approach through relevance leads to technology, but not deeply into social questions. The vocational approach raises these questions, but often answers them too technocratically. The transdisciplinary approach emphasizes the unity of the sciences and their associated technologies, but may exaggerate the power of science and technology in dealing with social problems. STS education is shallow without a historical dimension, but this easily becomes excessively academic. A philosophical approach can press some ideas of the nature of science, but only at the most elementary level. The sociology of science can explain the nature and role of science as a social institution, but is often unhelpfully sceptical in its conclusions. Finally, direct consideration of the world problematique raises many of the most important STS issues, but says little about how science and technology actually work, for good or for ill. (Ziman 1994, 31.)

2.3.3 Principles of STS education

When compared to the function of the traditional science curriculum, STS science represents a type of Kuhnian paradigm shift in goals. STS education embraces the successes of the old paradigm but with a different worldview on science teaching. Fundamentally, STS science teaching is student oriented, as contrasted with the scientist orientation of traditional science teaching. Students strive to understand their everyday experiences. To do so, students make sense out of their social
environment, their artificially constructed environment, and their natural environment. (Aikenhead 1994, 47-49.) STS instruction is a clear and appropriate way of practicing the so-called "constructivism" (Tsai 2001). Constructivist stories foreground the strongly local, indexical, and serendipitous character of knowledge construction in scientific laboratories; they also highlight the macro social nature of knowledge construction through its dependence on relationships with funding agencies, other researchers, those in charge at research sites, and the public. In a similar way, innovation in technology is not achieved by a special breed of engineers who draw on established knowledge and practical skills to solve engineering problems. Rather, novel engineering designs are said to emerge from networks of socio technical relations in which interpretations of social, scientific, and technological facts and artefacts compete for acceptance and domination. In one case, the reinterpretation of the rubber-tubed tire from an awkward accessory that reduced vibration to a winning feature of racing bicycles led to the low-wheeled bicycles that we know today. In another case, the divergent interpretations of “personal rapid transport” led to the abandonment of the French ARAMIS in spite of billions of francs of public money that funded the project over an eighteen-year period. (Roth et al. 1996.)

In STS approach students integrate their personal understandings of their social, artificially constructed, and natural environments. The study of natural world is called science, the study of the artificially constructed world is technology, and society is the social milieu. Teaching science through science-technology-society refers to teaching about natural phenomena in a manner that embeds science in the technological and social environments of the student. STS instruction aims to help students make sense out of their everyday experiences, and it does so in ways that support students’ natural tendency to integrate their personal understandings of their social, technological, and natural environments. (Aikenhead 1994, 47-49.) In a traditional science curriculum, the science content is taught in isolation from technology and society. In an STS science curriculum, this science content is connected and integrated with the students’ everyday worlds, and in a manner that mirrors students’ natural efforts at making sense out of those worlds. STS science is about making sense out of life today and for the future. STS science is expected to reverse the existing negative trends in enrolments, achievement, and career choices. STS approach
might be affecting other variables in the science classroom than in turn affect achievement in the sciences (Mbajiorgu and Ali 2002). STS – oriented instruction group of students could perform better in terms of the extent, richness and connection of cognitive structure outcomes than traditional group students do. STS instruction could be especially beneficial to students with its epistemological views being more oriented to constructivist views of science, particularly at an early stage of STS instruction. STS instruction could also show positive impacts on the female students’ cognitive structure. After a long period of research treatment, STS instruction could be effective for students of various epistemological orientations toward science. (Tsai 2001.) The introduction of STS interactions in physics and chemistry classes can help students to develop an improved comprehension and a more real image of these sciences, which allow students to understand better the role of scientists and how they work. STS interactions together with the teaching/learning model of science as research generate positive attitudes toward the study of physics and chemistry and increase the students’ interest in their study. (Solbes and Vilches 1997.)

Specifically, STS science is expected to increase general interest and public understanding in science, particularly among bright creative students who are discouraged by a boring and irrelevant curriculum. STS science is also expected to fill a critical void in the traditional curriculum – the social responsibility in collective decision making on issues related to science and technology. The pervasive goal of social responsibility in collective decision making leads to numerous related goals: individual empowerment; intellectual capabilities such as critical thinking, logical reasoning, creative problem solving, and decision making; national and global citizenship, usually “democracy” or “stewardship”; socially responsible action by individuals; and an skilled work force for business and industry. These goals emphasize an induction into a world increasingly shaped by science and technology, more than they support an induction into a scientific discipline. (Aikenhead 1994, 49; Aikenhead 2000, 53.) It is important to develop skills of natural inquiry, critical thinking, and decision making about science and technology and the links to the world they encounter already at an early age in the education (Pedretti 1999).

STS science courses differ widely because of their different goals. On closer examination, however, this variation reflects differences
in the balance among similar goals. The goals of STS education are: acquisition of knowledge (concepts within, and concepts about, science and technology) for personal matters, civic concerns, or cultural perspectives; development of learning skills (processes of scientific and technological inquiry) for information gathering, problem solving, and decision making; development of values and ideas (dealing with the interactions among science, technology, and society) for local issues, public policies, and global problems or cognitive competency — standardized knowledge and skills needed for reading and speaking accurately about STS issues (for example, conservation of energy in science means something different than it does in everyday use, controlling variables is essential to good experiments, research and development is a combination of science and technology; rational/academic — a grasp of the epistemology and sociology of science required for understanding the dynamics at play in STS issues, for example scientific observations are theory-laden, scientific beliefs are reached by consensus making, epidemiology can have political dimensions; personal — students understand their everyday lives better, for example money invested in insulation has benefits in cold climates, you are what you eat, giving careful attention to worlds on labels can save you problems; social action — students participate in responsible political action, for example making consumer choices to affect global environments, writing letters to government or industries, participating in resolution of a local issue. All goals may have a place within a single curriculum, but some goals have higher priority than others. For example, the goal — social action — is usually a high priority in some environmental courses. An STS science course would likely embrace all goals, though each goal with a different emphasis. The function of the old science curriculum has been to prepare students for the next level of education and to teach correct answers. These functions are not ignored in STS science curriculum, but they are not given as strong an emphasis. (Aikenhead 1994, 50-51.) After practising STS instruction the teacher can view STS as an integrated curriculum that promotes students’ scientific knowledge, process skills, citizenship behaviours, and decision-making abilities. The teacher can possess many constructivist-oriented teaching approaches recommended by science educators, for instance, cooperative learning, discussion activities, and conceptual change strategies. The actual implementation clearly helps the teacher
conceptualize the rationales and strategies of STS instruction, and then demonstrate a considerable pedagogical knowledge growth about STS. (Tsai 2001.)

2.3.4 Categories of STS education

Categories of STS education characterize science education in terms of:
- Content structure – the proposition of STS content compared with traditional science content, and the way the two are combined;
- Student evaluation – the relative emphasis given to STS versus traditional content. The description is an approximate indicator of relative emphasis, rather than a prescription for classroom practice.
- Concrete examples of STS science.

The spectrum expresses the relative importance given by STS content in a science course. At one end of the spectrum, STS content is given the lowest priority compared with traditional science content, while at the other end, it is given the highest priority. The eight categories of the spectrum are as follows: (1) motivation by STS content, (2) casual infusion of STS content, (3) purposeful infusion of STS content, (4) singular discipline through STS content, (5) science through STS content, (6) science along with STS content, (7) infusion of science into STS content, and (8) STS content (Table 2) (Aikenhead 1994; 2000).

These categories are applied in different countries and faculties in many different ways. According to the different approaches mentioned before STS education can also refer more to society education. Then the education deals with the role of science in the society rather than with the content knowledge of science. An example of this kind of STS education can be found in the European ESCT net (www.esst. uio.no). But, the science content knowledge can not be forgotten. As Greenwood and Schribner-MacLean (1997) state

“We would no more expect an adult to teach a child to read if that adult could not read him/herself; neither do we ask a teacher to teach a second language to a student when the teacher speaks only English. Yet we ask teachers to teach science without having first developed their knowledge base.”

In this study STS education refers particularly to science education which has also integrated society and technology dimensions and is realized under the title Basic Studies in Science and Technology.
Table 2. Categories of STS education (Aikenhead 1994; 2000)

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Motivation by STS content</strong></td>
<td>Traditional school science, plus a mention of STS content in order to make a lesson more interesting. Students are not assessed on the STS content.</td>
</tr>
<tr>
<td>2. <strong>Casual infusion of STS content</strong></td>
<td>Traditional school science, plus a short study of STS content attached onto the science topic. The STS content does not follow cohesive themes. Students are assessed mostly on pure science content and usually only superficially on the STS content (for instance, 5% STS, 95% science).</td>
</tr>
<tr>
<td>3. <strong>Purposeful infusion of STS content</strong></td>
<td>Traditional school science, plus a series of short studies of STS content integrated into science topics, in order to systematically explore the STS content. This content forms cohesive themes. Students are assessed to some degree on their understanding of the STS content (for instance, 10% STS, 90% science).</td>
</tr>
<tr>
<td>4. <strong>Singular discipline through STS content</strong></td>
<td>STS content serves as an organizer for the science content and its sequence. The science content is selected from one science discipline. A listing of pure science topics looks quite similar to a category 3 science course, though the sequence would be quite different. Students are assessed on their understanding of the STS content (for instance, 20% STS, 80% science).</td>
</tr>
<tr>
<td>5. <strong>Science through STS content</strong></td>
<td>STS content serves as an organizer for the science content and its sequence. The science content is multidisciplinary, as dictated by the STS content. A listing of pure science topics looks like a selection of important science topics from a variety of traditional school science courses. Students are assessed on their understanding of the STS content, but not as extensively as they are on the pure science content (for example, 30% STS, 70% science).</td>
</tr>
<tr>
<td>6. <strong>Science along with STS content</strong></td>
<td>STS content is the focus on instruction. Relevant science content enriches this learning. Students are assessed about equally on the STS and pure science content.</td>
</tr>
<tr>
<td>7. <strong>Infusion of science into STS content</strong></td>
<td>STS content is the focus of instruction. Relevant science content is mentioned, but not systematically taught. Emphasis may be given to broad scientific principles. Students are primarily assessed on the STS content, and only partially on pure science content (for example, 80% STS, 20% science).</td>
</tr>
<tr>
<td>8. <strong>STS contents</strong></td>
<td>A major technology or social issue is studied. Science content is mentioned but only to indicate an existing link to science. Students are not assessed on pure science content to any appreciable degree.</td>
</tr>
</tbody>
</table>
2.4 Science and Technology Education

Science and Technology Education in Joensuu forms the context of this study. The education is based on the modern view of science education and on the principles of STS education considered in the preceding chapters. Because of this connection Science and Technology Education is presented in this chapter.

Science and Technology Education - Basic Studies in Science and Technology - at the University of Joensuu started in an academic year 1998-1999 within the LUMA programme (see chapter Introduction). This education forms minor studies mainly for primary school teacher students (primary level at the comprehensive school, classes from 1 to 6). The education follows the STS category levels 4 and 5 in the Table 2 with about 20-30 % STS-content built inside the science education. The education, total of 15 credits, consists of six separate courses which are shown in Figure 2.

![Diagram showing the structure of the Science and Technology Education courses]

**Figure 2.** Basic Studies (15 credits) in Science and Technology

The aim of the Basic Studies in Science and Technology is among other things to acquire scientific understanding and to widen the worldview, to understand the most central concepts and the general features of the structures of theories in science, to understand the teaching of these subjects on different levels of the education and to understand the mutual relations between basic sciences, technology, society and people. The courses aim to help primary school teacher students
develop a theoretical framework for teaching science at the elementary level, a repertoire of methods for teaching science, favourable attitudes toward science and science teaching, and deeper understanding of some science content area and of the relations between sciences, technology and society.

The education is conducted in co-operation with the Faculty of Science, and the Faculty of Education. The students are strongly recommended to take the courses in the order shown in Figure 2 during one academic year. Science and Technology studies start with an introductory course arranged by the Department of Applied Education. The geography, biology, chemistry and physics courses follow and are arranged by the respective departments of the Faculty of Sciences. The last course, arranged by the Department of Applied Education considers the interrelations between science, technology and society. The science discipline courses contain mainly subject contents and less STS-content whereas the courses carried out by the Department of Applied Education include mainly STS-content. During the first and the last course, also the pedagogy of science is discussed and practiced. The pedagogy of the education takes up a place in the right upper corner in the continuum of instruction and learning shown below as a triangle in a former Figure 1.
During the academic year 1999-2000 the scientific and technological knowledge and action, attitudes of children, teachers and adults to science and pedagogical aspects of science instruction were discussed during the lectures in the introductory course of “Science and Technology as a knowledge and action”. Hands-on experiments and inquiries especially were pointed out. During the course, in a given period, the students also had to read newspapers and collect all the articles which they thought concerned science and/or technology. Then, the students explained in pairs or in small groups why each article, in their opinion, concerned science or technology. The articles were presented to the other students and the results were compared and thoughts discussed in seminars after the lectures.

After the introductory course the students took the subject courses which dealt with STS-issues mainly as technological applications and as everyday phenomena. Subject courses included also practices, field or laboratory work. Geography course included a visit to the famous Finnish national park Koli near Joensuu where the tracks of the Ice Age can be seen. Biology, chemistry and physics courses included laboratory practices. During the lectures in the physics course the students familiarized themselves with the following physics topics: mechanics, electricity, thermodynamics and optics. Afterwards they made small closed inquiries which were instructed in detail. To avoid “cookbook inquiries”, they had to measure variables and relationships between factors, draw figures and report the inquiries. Physics and chemistry courses included also a teaching project during which the students had to teach either physics or chemistry subject in an elementary class and report their instruction. They were free to choose the school, class, and subject which was most often, however, given by the school.

For the last course the students returned back to the Department of Applied Education. During the last course the lectures concerned about Finnish industry areas. Besides general industry overview also STS approach in science education and sustainable development questions were discussed. The students also carried out an industry project. During the project they visited Perlos, a plastics industry company in Joensuu, and familiarized themselves with the products and production of the company. They worked in pairs or in small groups and reported about the environmental management system of the company, about two of the products of the company (mobile phone
and asthma inhalator), about the personnel management, and about the company’s practises with the goschools. Each group worked with one theme. They collected data from the web-sides of the company and by interviewing the personnel of the company and pupils in the goschool. Finally, the students carried out a technology project in which they designed and built a washing machine by the aid of LEGOs and the Logo Programming.
3 Methodological framework and solutions of inquiry

To form a picture of the primary school teacher students’ language in physics topics, and of their thoughts on science from the viewpoint of science instruction, the empirical part of the study is conducted by carrying out two studies among one group of the primary school teacher students. As a research field language and views are quite substantial and methodologically rich areas, but in Science and Technology Education context, the role and forms of students’ thoughts have not been clarified enough. However, it has become evident that the changes in students’ language and thoughts are tied to the processes in which learning is constructed. In this study the change of the students’ ideas concerning science in the teacher education context is seen as a specific part of the learning process. These studies have been planned by using two different methods (questionnaire concerning physics problems, and narratives). Both of the studies in this naturalistic case study have similar purposes: to form the student teachers’ views of science and science instruction in a special context of Science and Technology Education.

3.1 Specification of the inquiry

Different people give, from one culture to another and also inside a culture, different meanings for the same phenomena or cultural products. The embodying of the phenomena must, however, be in sufficient degree uniform or homogeneous, to make the common understanding possible at all. The research of meanings and interpretations is interesting particularly, when different interpretations and meanings from a cultural product differ. Obviously many such things, which have different meanings and interpretations for primary school teacher students, and for those who have science education background, are connected with science.

From our everyday experience we know how it often happens in discussion or particularly in instruction that people do not speak about the same thing because their conceptions of the issue differ from each other. In Finland it is said that “one speaks about the fence, the other
about the pole of the fence”, meaning that the latter does not see the
thing as a whole. The discussion becomes even more difficult when
participants understand the nature of the thing in a different way.

At the very beginning of my career in education I felt that I needed
to know the existing conceptions of my students better in order to
construct my instruction from these conceptions. To succeed in the
cooperation with the primary school teacher students it is necessary to
find the common ground for discussions. We have to build the common
world of meanings or the common framework. The significance of the
differences in the experiences can be found in the following short
example (Syrijälä et al. 1995, 114).

"An adult was telling a fairy tale about Snow White for a
four-year-old. In the fairy tale Snow White runs away from
her strict godmother, lives with the seven dwarfs, and finally
arrives back home to the King’s castle. The fairy tale ends. A
four-year-old asks: “What did the sheep do then?“ During the
previous summer the child had familiarized himself with a
sheep called Snow White. When listening to the story the child
had had a mental image of the sheep in her/his mind.”

Mezirow (1995, 201) captures the situation perfectly by saying that
the first condition for encouraging the learner to critical reflection is
that the educator sees the world in the same way as the learner does.
This means that teachers should become phenomenological detectives,
familiarize themselves with their learners’ worldviews and assumptions
and only after that start to investigate the methods of how to encourage
the students to abandon the familiar and routinized learning paradigms.
I decided to be a phenomenological detective, too, and tried to see the
world of science “in the eyes of my students”.

3.1.1 The research questions

When exploring the process of science studies, the main interest
focuses on what students highlight, and especially on the science view
aspect. Thus, this study addresses firstly the knowledge about what the
primary school teacher students’ highlight in the instructional context
of Science and Technology Education. Secondly, this study addresses
the knowledge about how changes in the view of science occur in the
minds of students. At this phase the different ways to explain and tell,
as also the views, are determined and presented.
Study 1: Knowledge type in physics?

Based on the literature review it seems that the researchers in the field of science education have limited knowledge about the knowledge type of primary school teacher students in the context of science, especially in physics. Thus, the ideas about the type of knowledge need to be discussed in respect of science education. How the knowledge construction, which emerges in the science education process, is seen in the use of language. Accordingly, besides the language itself in this study, the interest concentrates also on the changes in languages. This is clarified because more information is needed on how the discourse in instructional situation supports the construction of knowledge structures. On the other hand, the development of science instruction in teacher education is seen to have an essential role in fostering good science instruction at the primary level. These views are the starting points for the first research question in this study.

1. What kind of knowledge do the students have of physics phenomena?
   1.1 How do the students explain physics phenomena?
   1.2 What kind of differences exist in the explanations of different physics topics?
   1.3 How do the explanations change during the education period?
   1.4 How are the changes in students’ explanations understood in respect of the physics education?

Study 2: View of science and science instruction?

The developmental attempts in Science and Technology Education imply, besides the knowledge of the students’ language, also the knowledge of the present situation of the students’ ideas. Thus the students’ thoughts need to be discussed in respect of Science and Technology Education and also taking into account everyday and school learning. On the other hand, based on the literature review, it seems that the researchers in the field of teacher education have limited knowledge about the thoughts of students on science and science instruction. Thus, also the students’ views need to be discussed in respect of science education. These aspects are included in order to clarify the second research question.
2. How do the students experience Science and Technology Education?
   2.1 What do the students highlight in the education?
   2.2 How do the students describe science education?
   If the students describe science, two questions can be added.
   2.3 How do the students describe science?
   2.4 What are their views of science?
   And, if the students describe science instruction, three further questions can be added.
   2.5 How do the students describe science instruction?
   2.6 What are their views of science instruction?
   2.7 Are the students’ approaches to learning science influenced by their views of science?

Because the context variables of both studies have an ambiguous nature, being partly tied together and partly separated when interpreting the research results, the empirical findings of these research questions are presented in two parts and tied finally together. The study paradigm follows constructivism. Because there is a distinction between these two different areas of the study, language and thoughts, the study includes two different approaches to research. The third research question combines the two areas of the study.

3. How are the students’ views of science and of science instruction related to the knowledge types that the students use?

3.1.2 Philosophical commitments of the study

The construction of the meaning is a philosophical issue, and thus the basic elements of the philosophical commitments are required to be established to reveal the nature of knowledge and the nature of the world in the studies. Inquiry paradigms are seen as a set of basic beliefs from ontological, epistemological and methodological foundations (see Lincoln and Cuba 2000, 165). The researcher approaches the world with a set of ideas, a framework (theory, ontology) that specifies a set of questions (epistemology) that she or he then examines in specific ways (methodology, analysis). That is, the researcher collects empirical material relating to the question and then analyzes and writes about it.

The philosophical understanding of this study is mainly based on a constructivist paradigm. Criteria for judging reality is derived from
community consensus regarding what is ‘real’, what is useful, and what has significance (especially significance for the action and further steps). The ontological questions are trying to find answers to what the form and nature of the reality is and, therefore what is to be known about it. The ontology in constructivist paradigm is relativist meaning that there are multiple realities. From ontological perspective the reality can be made up of the following ontological elements: feeling, attitudes, beliefs, thoughts, views, representations, stories, narratives, texts, discourses, codes, languages (see Mason 2002, 14-15). Realities are seen in the form of multiple, intangible mental constructions, based on social situations and experiences, local and specific in nature, and their form and content is dependent on the constructions that the individual persons are holding (see Robson 2002, 25). This study about the students’ thoughts suggest an ontological position which says that every student holds a specific kind of thoughts on science, her or his reality, thus there are many realities, and those thoughts are meaningful components of the social world where the student lives.

Epistemology tries to find answers to questions such as the nature of knowledge or evidence. Knowledge of what others are doing and saying always depends upon some background or context of other meanings, beliefs, values, practices, and so forth. In terms of epistemology these research topics are suggesting that distinctive dimensions of the social world are knowable - that it is possible to generate knowledge about and evidence for them. The epistemology of this study is mainly subjectivist, which means that the one who knows and the one who responds co-creates understandings.

The nature of this study is based on the science instruction theories. The instruction is seen from the viewpoint of constructivist framework and the teacher students from the pedagogical viewpoint. The students are seen as human beings who have had contact with science before the education, in informal settings and schools and then later in teacher education. This study is dealing with qualitative research tradition from the view point of the world or reality as also verbal explanations. As a qualitative research, this study aims to catch a deep and holistic picture of the complex view of science which the students as prospective teachers have constructed. According to the constructivist paradigm methodological procedures involve a naturalistic set of procedures existing in the natural world. Everything
is always seen through interpretation, thus everything, in fact, is constituted by interpretation.

The purposes of this study have different dimensions. Firstly, the aim is to understand the students, where a pure curiosity, my own nature as a researcher, has a remarkable role. However, for me as a teacher, also the understanding of the students is necessary for successful instruction. Secondly, for me as a teacher and a project leader, the purpose of this study is to get information for the developmental work in the education. And finally, as a member of the academic community, my purpose is to acquire the doctoral degree in education.

The words of Antoine de Saint-Exupéry in The Little Prince describe my work well.

"You can imagine how my curiosity was aroused by the half-confidence about the "other planets". I made a great effort, therefore, to find out more on this subject. "My little man, where do you come from? What is this where you live, of which you speak?"

### 3.2 The study design and strategies of inquiry

The two experimental case studies in this inquiry are both descriptive and analytical by their nature. The two study processes are set to understand the world of the primary school teacher students in the science context. According Denzin and Lincoln (2000, 371) the strategies of inquiry connect researchers to specific approaches and methods for collecting and analysing empirical data. For Janesick (2000, 379) qualitative research design is very much like choreography. The essence of good qualitative research design is the use of a set of the procedures that are simultaneously open-ended and rigorous and do justice to the complexity of the social setting under study. A good choreographer captures the complexity of the story by using rigorous and tested procedures and in fact refuses to be limited only to one approach to choreography. The qualitative researcher uses various techniques and rigorous and tested procedures in working to capture the nuance and complexity of the social situation under study.

The nature of this study is based on the constructivist framework of the students’ views of science. The students are seen as subjective, contextual, self-determining and dynamic beings. The characteristics
of the qualitative research tradition are embedded to each sub-study and its different phases. At the beginning of this study I thought as creatively and fully as possible about the methods in the natural context. Data was collected and examined throughout one year in order to develop a more complete understanding of the students’ views. For practical reasons the choices were limited later. All possible approaches to the research questions have been considered about in order to avoid the arbitrary or inappropriately limitations. A map of possible research methods and data sources are shown in Figure 3.

Figure 3. The study design
Qualitative research is both exciting and challenging and can be characterized in many ways. Qualitative research has, according to Mason (2002, 6), the ability to discover truths or to represent the realities of others. One of the starting points is that qualitative research describes real but complex life. Qualitative design is also holistic. It looks at the whole picture, and begins with a search for understanding of the whole as Janesick (2000, 385) notes. She continues that qualitative design is focused on understanding, not necessarily on making predictions. This assumption is significant in this study. Qualitative research requires the construction of an authentic and compelling narrative of what has occurred in the study and various stories of the participants.

Qualitative research should be systematically and rigorously conducted, accountable for its quality and its claims, strategically conducted, yet flexible and contextual, it should involve self-scrutiny by the researcher, or active reflexivity (Mason 2002, 6). Mason thinks that qualitative research should produce explanations or arguments, rather than claim to offer mere descriptions which is somewhat contrary to the view of Janesick. Explanations or arguments should be generalizable in some way, or have some demonstrable wider resonance. It is characteristic for qualitative research that it has no hypothesis and it is data based. In qualitative inquiry the researcher is a part of the study. Even when empathetic and respectful towards each person’s realities, the researcher decides what the case’s own story is, or at least what will be included in the report. Case study has been chosen for the strategy in this study. I use the term view (näkemys) to express the whole. Conceptions, more specific and individual expressions are searched from the data, and the whole model of the thoughts, the “view”, is formed from these conceptions.

3.3 Naturalistic case study

Constructivist paradigm requires a naturalistic set of methodological procedures. Naturalistic inquiries should be assessed on the basis of trustworthiness and authenticity. According to Sadler (2002, 126) naturalistic inquirers do typically most of their data reduction and analysis using a marvellously designed piece of apparatus, the brain. He continues that no device or system devised so far, irrespective of
size or complexity, can match its ability to extract information from noisy environments. But, of course, any inferences drawn from the data can be only as good as native cognitive mechanisms allow. Robson (1993, 61) lists the characteristics of naturalistic enquiry adapted from Lincoln and Guba. At first naturalistic research is carried out in the natural setting or context of the entity studied. Naturalistic research uses tacit knowledge, qualitative methods, and prefers the inductive data analysis over the deductive one. Research design emerges from the interaction with the study. Whenever the constructed realities of separate cultures or individuals come into contact with each other, no person leaves such an encounter with earlier constructions intact. The researcher is necessarily intrusive upon the environment and persons being studied and can not leave the research setting without new constructions of reality. The characteristics of naturalistic inquiry shown by Erlandson et al (1993) are parallel to the characteristics of constructivist paradigm (see also Robson 2002, 24-27). Even when there are no or little differences between these concepts and although ‘naturalistic’ is nowadays replaced by ‘constructivist’, in this study I prefer the use of ‘naturalistic’ inquiry to point out the naturalistic character of the inquiry.

Case studies have become one of the most common ways to do qualitative inquiry, but they are neither new nor essentially qualitative, Stake (2000, 435) starts his presentation about case studies. He continues that case study is not a methodological choice but a choice of what will be studied. As a form of research, case study is defined by the interest in individual cases, not by the methods of inquiry used. A case study is both a process of inquiry about the case and the product of that inquiry. The case study is a research strategy which focuses on understanding the dynamics present at single settings. Case studies can involve either single or multiple cases, and numerous levels of analysis. Case studies typically combine data collection methods. A study undertaken because, first and last, the researcher wants better understanding of this particular case, is called an intrinsic case study by Stake (2000, 437). It is undertaken primarily because the case represents other cases or illustrates a particular trait or problem, but above all because, in all its particularity and ordinariness, the case itself is of interest. This study is mainly an intrinsic case study, although it together with the pilot study and possible later studies can also be seen as a collective case study.
The research strategy of this study is case study. It is focused on a phenomenon in context, typically in situations where the boundary between the phenomenon and its context is not clear; and using multiple methods of evidence or data collection. Case study is empirical in the sense of relying on the collection of evidence about what is going on and being about the particular; a study of that specific case (Robson 1993, 52; 2002, 178). Because the base for this study is in Science and Technology Education with quite small groups, case study was required from this starting point.

This study focuses on a phenomenon how students view science, so it is also a phenomenological study. Phenomenology investigates the ways events appear when theories and constructs are put aside for a moment by the researcher (Fischer and Wertz 2002). In doing so, phenomenology studies the ways a persons’s world is inevitably formed for the person who lives in it. The study of primary school teacher students’ thoughts is based on the framework of science education discussed in the theoretical part of this study. It limits the variations of students’ views of education. In phenomenographical approach in general there is an intention to see the phenomenon as reduced as possible without pre-assumptions about the nature of the phenomenon. By the aid of the phenomenological inquiry it is aspired to describe peoples’ qualitatively different experiences about the reality. Phenomenographical inquiry studies in most cases learning. Learning is a qualitative change in thinking.

Philosophical hermeneutics is a way of representing the notion of interpretative understanding on the background of this study, too. The researcher is engaged in a critical analysis or explanation of the text using the method of the hermeneutics circle (Schwandt 2000, 194-195). An interpreter’s self-understanding neither affects nor is affected by the negotiation on understanding. Indeed, insofar as interpreters and linguistic objects are presumed to be distinct, self-understanding is believed to bias and distort successful interpretation. Philosophical hermeneutics argues that understanding is not, in the first place, a procedure- or rule-governed undertaking; rather, it is a very condition of being human. Understanding is interpretation. (Schwandt 2000, 194-195.) Phenomena, which are investigated in this study, are mental constructions in the minds of the human beings and the knowledge of these is a construction of these constructions. Tradition
is not something that is external, objective, and past-something from which we can free and distance ourselves. Tradition is a living force that enters into all understanding and despite the fact that traditions operate for the most part behind our backs, they are already there, ahead of us, conditioning our interpretations. Although preconceptions, prejudices, or prejudgments suggest the initial conceptions that an interpreter brings to the interpretation of an object or another person, the interpreter risks those prejudices in the encounter with what is to be interpreted. Understanding is participative, conversational, and dialogic. It is always bound up with language and is achieved only through the logic of question and answer. Understanding is something that is produced in that dialogue, not something reproduced by an interpreter through an analysis of what she or he seeks to understand. (Schwandt 2000, 194-195.)

3.4 The subjects of the study

This study was conducted within Science and Technology Education for the teacher students. In the beginning of their education the students were informed about the research to be conducted during the education. All written reports, exam papers or practise reports, and bulletins could be used as a research material. The research had to be understood as a part of the university activities and of the developmental work.

The subjects for this study were the seventeen students who were participating the education in the academic year during the research. All students were primary school teacher students and they were doing their third year in their education. The students had completed most of their pedagogical studies. Teachers’ pedagogical studies (35 credits in total) are a part of their educational studies. Primary school teacher students’ major subject is educational science which they study for 75 credits. They write also their Master thesis in education. Science and Technology Education is voluntary and the students, who had chosen the education as a part of their Master’s degree, made up about 22% of all the third year students.

The material collected for the study belonged to the normal work of the students studying for the grade. The requirement for the study
was a natural and authentic context. The education had not been
designed especially for the research, it was normal education conducted
by several teachers in the context of technology and society on different
levels. I was one of the teachers and mainly responsible of the science
pedagogy education and STS-education within the first and the last
courses, as also the teacher of the physics course.

Students of the preceding academic year had been a pilot group.
The results of this pilot study are shown in my master thesis (Keinonen
2001) and were presented in JULIS symposium (Keinonen 2002). The
pilot group of 8 students consisted of primary school teacher students,
pre-school teacher students and special education students. Their age
and experience distributions were larger than those of the research
group’s in this study.

3.5 Methods of collecting the data

Based on the results of the pilot study I decided to collect the data in a
more multifaceted way. The physics questions are due to the experience
of the pilot study designed to be from four different physics topics
instead of the two in the pilot study. In this study the data is collected
open minded: explanations for the concepts (science, technology,
science education, technology education) in the beginning lecture of
the education in the autumn term 1999, explanations for the physics
phenomena in the spring term 2000, results of the physics exam in the
spring term 2000, project reports especially of the newspaper project
in the autumn term 1999, metaphors of science and technology in the
context of the physics questionnaire in the spring term 2000, homeworks of the physics course in the spring term 2000, laboratory
practise reports in the physics course in the spring term 2000, students’
register data, narratives written outside the lectures after the education
in May 2000. I carried out all the designing and collection of the data
myself as a teacher of the courses during which the data was collected.
During this study the explanations of the physics phenomena, which
can be seen as one kind of discourse (as almost all other data of this
study) and narratives written by the students were raised to be the most
informal from the point of view of the research questions. Discourses
and narratives as data will be discussed in this chapter.
Bruner (1986, 11) divides cognitive functioning or thoughts into two modes, a good story and well-formed argument, each providing distinctive ways of ordering experience in constructing reality. They differ radically in their procedures for verification. A good story and a well-formed argument are different by nature. Both can be used as means of convincing each other. Yet, they convince in a fundamentally different way: arguments convince you because of their truth, stories because of their lifelikeness. The one verifies by eventual appeals to procedures in establishing formal and empirical proof, the other establishes not truth but verisimilitude. The paradigmatic or logico-scientific mode, attempts to fulfil the ideal of a formal, mathematical system of description and explanation. It employs categorization of conceptualization and the operations by which the categories are established, instantiated, idealized, and relate one to the other to form a system. The imaginative application of the narrative mode leads to good stories. It deals with human or human-like intention and action and the vicissitudes and consequences that mark their course. It strives to make its timeless miracles into particulars of experience, and to locate the experience in time and place.

3.5.1 Written explanations as discourses?

If the ability to reason is clearly an obvious component in being scientific, then one of the low-level natures of science objectives could be to teach some elementary formal and informal logic (Matthews 1998). Paradigmatic or logico-scientific mode in arguments, reasoning or explanations is based on a text. The focus directed to language in a text, or to discourse, as it has come to be known, can give valuable information about everyday life. The use of discourse has been accompanied by the development of new methods which are designed for the close analysis of talk or writing. The methods are sometimes called discourse analysis, but according to Wood and Kroger (2000) discourse analysis is not only about a method; it is also a perspective on the nature of language and its relationship to the central issues of the social sciences. They see discourse analysis as a related collection of approaches to discourse, approaches that entail not only practices of data collection and analysis, but also a set of metatheoretical and theoretical assumptions and a body of research claims and studies
(as also Potter 1997). Data collection and analysis are a vital part of discourse analysis, but they do not, in themselves, constitute to the whole of discourse analysis.

According to Roth and McGinn (1998) discourse analysis is a radical new perspective that is grounded on the constructive, everyday use of language and has implications for many social-psychological phenomena. They state that discourse analysts have demonstrated the pitfalls of treating everyday discourse as a pathway to attitudes, beliefs, and knowledge. When the events are constructed in the realm not of nature but of culture they are, as such, wholly enmeshed in the complexities of language. The study of human beings as social beings is concerned with our relations to the symbolic world, such study involves examining how we acquire and use language. The nature of the entities under study is that of material things located in space-time producing a world locked together by causal relations. Peoples' points are the nodes of interaction created by people as social beings who must act in concert with their fellow social beings; in doing so, they create a world that is locked together not by causal relations but by conventions, shared rules, story lines, and narratives (Wood and Kroger 2000, xii).

According to Wood and Kroger (2000, 3) discourse analysis involves ways of thinking about discourse (theoretical and metatheoretical elements) and ways of treating discourse as data (methodological elements). There are multiple versions of the discourse-analytic perspective, and thus multiple definitions of discourse and what counts as discourse. In this study written language is seen as discourse. The focus is not on language as an abstract entity, but as the medium for interaction; analysis of discourse becomes, then, analysis of what people do or how they do it. This viewpoint to discourse is essential in this study. Language is not taken to be simply a tool for description and a medium of communication, but as practised, as a way of doing things. Text-based documents are social productions. They are situated constructions, particular kinds of representations shaped by certain conventions and understandings which are properly studied through the methods of discourse analysis. For example, the use of formal language produces a very different style from the use of informal language. Just as a form or a style is a part of a content, the content is a part of the style. Discourse analysts generally do not focus on words
as such, as linguistic objects. Nor do they focus on the referential function of words. In this study I also have to look at the words, physics concepts, which students use and how they use them. But I am not interested in the language itself, rather in what is behind it. The function, in the sense of what kinds of words students use to explain physics phenomena, is, however, on the focus.

Qualitative researcher can be seen as a bricoleur and bricolage sometimes requires developing own particular techniques or identifying devices, practices, or resources that have not been discussed before. In this study I have to look at the explanations in the way suitable for the context of the study. There is a need of content analysis too, in the meaning, whether the students use scientific concepts or not. Discourse analysis also involves interpretative work with categorization. While reading we should think, how the discourse is being read, the obvious could be the starting point, consider what there is not, what is included, look how the text is structured, and ask whether a particular word of text relies on some assumption. The more familiar the researcher is with the language and how it is used, the more sensitive the analysis will be. However, because I am familiar with the physics, there is also a danger of interpreting the discourse too rigorously. It must be remembered that the researcher enters discourse analysis as a member of the culture. (see Wood and Kroger 2000.)

The focus of discourse analysis on participants’ meaning, together with the recognition that our own concepts construct the way we see the world, means that analytic activity involves interplay between the data and our notions about it. Analytical concepts can suggest what to look for and help us interpret what we see. Concepts may be of a wide variety of types and levels; they may relate to content (account); features (intensifiers); form (direct, indirect; simple, elaborate); structure (hierarchical, e.g., movements-action; sequential, e.g., turn taking, adjacency pairs); or function (e.g., constructing a motive). (Wood and Kroger 2000, 99.)

At the beginning and at the end of the physics course (3 credits in total) in the spring term 2000, the teacher students filled a questionnaire including physics questions in mechanics, thermodynamics, optics and electricity (Appendix A). At first they chose one of the four given answers. After that they explained the physics phenomenon under consideration with their own words. The questions were chosen from
a common book written for the public to avoid too high speciality in the topics. In this book called ‘When is the Moon brightest?’ the writers introduce questions concerning different science phenomena. They also give answers to the questions. In principle the public should understand the explanations in the book. Due to the findings of the pilot study questions in four different topics were chosen. Most of the concepts discussed in these questions are discussed in the primary school level, too, although not at the same level than in the answers in the book mentioned before. The degree of difficulty of the questions changed remarkably. The reader is reminded that more than the concepts or correct answers, the language is under interest. These explanations were analysed partly from the viewpoint of discourse, partly of content analysis, and a categorization suitable for the context of this study was developed.

3.5.2 Narratives

A narrative differs from other forms of discourse. The imaginative application of the narrative mode leads to good stories. A story gives the possibility to understand the world in a different way than a paradigmatic form of knowledge (Heikkinen 2000). Stories or narratives can be seen as knowledge constructor. Narrativity is no method, no school, but an incoherent formation of inquiries connected to narratives. It is a broad framework, with the characteristics that the attention is directed to narratives as a producer and a medium of the reality. There is no binding theory of a narrative but instead great conceptual diversity (Kohler Riessman 2002, 229). A narrative analysis refers to a large number and wide variety of approaches. They range from those in which the term narrative is used interchangeably with account; to those in which discourse is viewed as a narrative because it has at least some features of a conventional narrative structure; to those in which discourse is analyzed by using narrative principles. (Wood and Kroger 2000, 104.)

Narratives or stories

Locating narratives of personal experience for analysis is not difficult. Narratives are ubiquitous in everyday life. We can all think of a conversation in which someone tells in details what he has said, what
he said, what happened next – a recapitulation of every nuance of a moment that has had special meaning for her/him. Telling stories about past events seems to be a universal human activity, one of the first forms of discourse we learn as children and which is used throughout the life course by people of all social backgrounds in a wide array of settings. A personal narrative refers to a talk organized around consequential events. A teller in a conversation takes the listener into a past time or “world” and recapitulates what has happened to make a point. Investigators do not have direct access to another person’s experience. We deal with ambiguous representations of it, a talk and a text. (see Kohler Riessman 2002, 219.)

The concept of narrativity has many purposes and aims for researchers. A narrative is understood as a spoken or written text giving an account of an event/action or series of events/actions, chronologically connected (Czarniawska, 2004, 17). According to Bruner (1990, 43) the principal property of narratives is inherent sequentiality, a narrative is composed of a unique sequence of events, mental states, happenings involving human beings as characters or actors. All narratives are stories about a specific past event, and they have common properties. Individuals relate to experiences by using a variety of narrative genres. Genres of narrative, with their distinctive styles and structures, are modes of representation that tellers choose (Kohler Riessmann 2002, 231). Stories reach sad or comic or absurd denouements, while theoretical arguments are simply conclusive or inconclusive. A story must construct two landscapes simultaneously. One is the landscape of action, where the constituents are the arguments of action: agent, intention or goal, situation, instrument, something corresponding to a “story grammar”. The other landscape is the landscape of consciousness: what those involved in the action know, think, or feel, or do not know, think, or feel. (Bruner 1986, 14.)

Traditionally a story has been viewed as being less or narrower than a narrative, Boje (2002, 1) states, but on the other hand Czarniawska (2004, 17) writes that narratives are purely chronological accounts and stories are emplotted narratives. According to Boje narratives require a plot, as well as coherence, but Czarniawska states that a narrative is not a story as it lacks a plot. To the narrative theory, according to Boje, a story is popular, without emplotment, a simple telling of chronology, which he calls ‘antenarrative’. Antenarrative is a fragmented, non-
linear, incoherent, collective, unplotted and pre-narrative speculation, a bet. To the traditional narrative methods antenarrative is an improper storytelling, a wager that a proper narrative can be constituted. A narrative tries to stand as elite, to be above a story. Stories can be analyzed with antenarrative methods. The focus is on the analysis of stories that are too unconstructed and fragmented to be analysed in traditional approaches. A narrative analysis combined with an antenarrative analysis can help this field be a more multi-voiced methodology that focuses on nonlinear, unplotted storytelling. A narrative is something that is narrated. A story is an account of incidents or events, but a narrative comes after and adds ‘plot’ and ‘coherence’ to the story line. To Boje a narrative is post-story. ‘Ante’ combined with ‘narratives’ means earlier than a narrative. Czarniawska’s story consisting of a plot comprising causally related episodes that culminate in a solution to a problem is a narrative for Boje (2002). But with Czarniawska’s definition for narrative ‘For them to become a narrative, they require a plot, that is, some way to bring them into a meaningful whole’, Boje agrees. There is a considerable disagreement about the precise definition of a narrative.

The use of the concept narrativity and its near concepts is unstable and nonuniform. Also in Finnish there are two words ‘kertomus’ and ‘tarina’, responding a narrative and a story. The concept story has stronger side meanings than the concept narrative. To Heikkinen (2000), who agrees with Polkinghorne, a narrative means an art of text, where the whole description of incidents going thematically in time is presented. The single episodes are connected together with a plot. A story includes connotation, which refers to unlikely, imaginative or emotional telling. ‘Kertomus’, a narrative, is a more neutral expression, but ‘tarina’, a story, refers to a narrative based on imagination and is thus unlike story. In literacy a narrative is the upper concept and a story one of its lower concepts, a conception which Charniawska disagrees and Boje adopts. For Bruner (1990, 44) a narrative could be ‘real’ or ‘imaginary’ without loss of its power as a story. A story, in a word, is vicarious experience, and the treasure of narratives into which we can enter includes ambiguously either “reports of real experience” or offerings of culturally shaped imagination (Bruner 1990, 54). Narrativity and story-telling are used in this inquiry in their broad sense as synonyms. However, narratives are seen as chronological
telling, without having a clear plot. A story includes more emotions or imaginative properties.

The meanings of narrativity

The concept of narrativity has been used at least in four different ways in scientific discussions (Heikkinen 2000). At first, it refers to knowledge process itself, to the way of knowledge and the nature of knowledge, when narrativity is often associated to constructivistic conception of knowledge. Secondly, it can be used in describing the nature of the data of inquiry. Thirdly, narrativity can be connected to the ways of analyzing data, and fourthly, the concept is jointed to the practical meaning of the narratives.

Narrativity and knowledge

Very often the narrativity is connected to the theoretical and cultural viewpoints of knowledge of constructivism or postmodernism. According to the narrative way of thinking, inquiry report is more a product than a record. Constructivism points out the view, according to which people construct knowledge and identity through stories. The knowledge about the world, as also the conceptions of every human being about himself, is the whole time building a story, which sharpens and changes its form. There is not just one reality, but are many realities constructed differently in human minds and social interaction. The inquiry can produce some authentic viewpoint, to the reality, but the belief of objective truth is reached. As in the construction of identities and everyday knowledge, also in the inquiry narrativity works continuously in two directions: narratives are both the starting point for the knowledge and also its results. Constructivistic conception about knowledge represents theoretical relativism of knowledge, according to which knowledge is relative depending on time, space and the position of the observer. Instead of the objectivity the postmodern way of thinking takes into account the contextuality of knowledge. The modern thought of the universal knowledge has been rejected: knowledge is always the knowledge of a knowing subject. That human being lives in a specific social and physical environment. Everything that s/he knows, comes from these connections of understanding. Narrative inquiry does not aspire to objectivity or generalizable knowledge, but
local, personal and subjective knowledge. For the narrativity this is its strength. The voice of the people is heard in a more authentic way. Knowledge is formed many-voiced and as a more layered entity than a set of small stories, but not as one universal and monological big story. The postmodern way of thinking has led to experimenting ways to write a collection of literally fictive texts or science discourses.

Narrative data

Narrativity has also been used in describing the material of the inquiry, the quality of the data. Narrative data, based on storytelling, is for example written answers, in which the persons under consideration have the possibility to express freely their conceptions about things in their own words. This has been the aim in this research in choosing the narratives for the data. In this context the narrativity of the data means prose text - narrative data is story-telling. In a more demanding meaning narrative data should have more of story characteristics such as the story has the beginning, the middle and the end and also an advancing plot. Kohler Riessman (2002, 231) refers to Labov in concluding that a "fully formed" narrative includes six common elements: abstract (summary of the substance of the narrative), orientation (time, place, situation, participants), complicating action (sequence of events), evaluation (significance and meaning of the action, attitude of the narrator), resolution (what finally happened), and coda (returns the perspective to the present) (see also Hlyvärinen 1998). With these structures, a teller constructs a story from a primary experience and interprets the significance of events in clauses and embedded evaluation. The sentences are not free in the sense that one could change their order and location in the narrative without changing the meaning of the narrative. In its simplest way narrative is whatever story-telling based data, which has no necessity to produce unbroken stories with plots. Narrative data can not be compressed into numbers or categories, but the interpretation is necessary. In the narrative inquiry the finding of the voice of the persons under consideration is pointed out.

Narrative analysis

Narrativity can refer also to the data handling: analysis of narratives or narrative analysis. Analysis of narratives directs attention to the
categorization of the narratives. In the narrative analysis the focus is in producing a new story from the narratives in the data. This classification is based on Bruner's (1986, 11) way to divide the knowledge to narrative cognition and paradigmatic cognition. In the analysis of narratives the paradigmatic knowledge is applied, when the data is graded and categorized, which has been the choice in this study. In the narrative analysis the narrative cognition is applied to making more synthesis than differentiation in categories. As the researcher combines texts, interprets and constructs, based on the original texts, it means that the final inquiry text is a construction by the researcher and in this sense fictional.

In addition to the basic narrative clause there is evaluation, and the function of evaluation is to offer the very point why a story has been told at all. Evaluative devices are saying: this was terrifying, dangerous, weird, wild, crazy; or amusing, hilarious, wonderful: more generally, that it was strange, uncommon, or unusual that is, worth reporting. In this study the interest is directed to what students hold worth reporting. The evaluative thickness might be an even more relevant feature than the contextual descriptive thickness. An evaluatively thin narrator may take a quasi-scientifically detached position by providing contextual details without much evaluation (Hyvärinen 1998, 160). The use of negative statement is one of the clearest and most frequent indication, that an expectation has not been met; modals and false starts indicate similar operation of expectation; the anyway is a common type of evidence that an expectation is violated; but there is similar evidence of a change in expectations (Tannen according to Hyvärinen 1998). Negative sentences exceed the positive ones in power of expression. They do not only report what has happened, they also give evidence of that something else was expected to take place. Evaluation and expectation are conceptually close to each other, because evaluations seem to need expectational horizon as regards to which the evaluations can be done. According to Hyvärinen (1998) the point of personal stories is best approached from the perspective of expectations and evaluation.

*Practical meaning of narrative*

Narratives can be seen as a practical medium. For many researchers the making of narrative inquiry means typically practical orientation.
The inquiry should benefit from persons, who are investigated. The purpose is not only to describe the world, but also to change it, by trying to improve the circumstances of the persons under investigation. In some connections stories are primarily as a practical medium, thus the knowledge formation of the inquiry has the second role. The purpose of the inquiry is not only to form new knowledge, but the practical values rise to be as most important.

Jerome Bruner's verisimilitude is not based on justification or arguments, but on the fact that the reader enters into the story and experiences it as a simulation of the reality. Verisimilitude is a feeling of something, which moves the reader through what the reader has her/himself experienced. The story opens up to the reader as a holistic emotional experience. It is essential that the world of the story opens up to the reader in such a believable way that the reader enters into the position of the characters in the story and understands the reasons of their actions under those circumstances where they live. The reality is inside the simulations.

The narrative viewpoint is close to the action research. In both of them it is essential that the researcher and the subject of the research are in near connection with each other, in some cases even the same person or group. Also, the idea that narrative research has to give benefit to the subjects of the research is essential— as also in the case of action research.

**Narrative research process**

There are, at a minimum, five levels of representation in research process by using narratives, with porous boundaries between them (Kohler-Riessman, 2002, 221). These levels are attending, telling, transcribing, analyzing, and reading. Attending to experience means, for Kohler-Riessman, a choice in which a selection from the totality of the unreflected, the primary experience is found. At this first level of representation the reality is actively constructed in new ways by thinking. The telling, the performance of a personal narrative, comes next, it represents the events, already ordered to some degree, with all the opportunities and constraints the form of discourse entails. In the telling there is an inevitable gap between the experience and any communication about it. Whatever form of recording is used, the story has to be represented in some form of text. The fourth level of
representation takes place as the investigator explicitly analyzes the transcript, or typically a number of them. There are decisions about form ordering and style of presentation. The anticipated response to the work inevitably shapes what is included and excluded. In the end, the analyst creates a meta-story about what has happened by telling what narratives signify, by editing and reshaping what has been told, and by turning it into a hybrid story. The fifth and final level of representation comes as the reader encounters the written report. The translation of the original narratives about experiences gets into the hands of others, who bring their own meanings to bear in their minds. Even for the same reader, the work can provoke quite different readings in different contexts. The teller selects features from the “whole” experience to narrate but adds other interpretive elements. A similar process occurs with transcribing, analyzing, and reading. Obviously, the agency of the teller is central in composing narratives from personal experience, but so also are the actions of others: listener, transcriber, analyst, and the reader. (see Kohler Riessman 2002, 221-228.)

According to Czarniawska explanations are possible because there is certain teleology – sense of purpose – in all lived narratives. She adds that it is a kind of circular teleology because it is not given beforehand but is created by the narrative. A life is lived with a goal but the most important aspect of life is the formulation and re-formulation of that goal. A narrative view gets rid of the problem by reinstating the role of goals as both the results and the antecedents of action. (Czarniawska 2004, 13.)

A way to depict the various uses of narrative and its analysis is shown in Figure 4. In this study the questions what the students say and how they say it are in focus. Textual aspects are less interesting. Students were asked to write a one-page-story about their Science and Technology Education. The aim of the open instructions for writing was to find out what kind of things students themselves would highlight. The narrative involves a selection of events for the telling. In the narrative not all the events in a situation are given equal significance, and some are left out altogether (Milne 1998). In this study students wrote the narrative at home after the education in May 2000 and the narrative did not influence their grades.
3.6 Relation between subjects and researcher

According to the constructivist paradigm both the researcher and the subject of the research have their own frameworks in which s/he embodies the reality and interprets it through her or his knowledge structures. From my framework of a physicist and a science teacher I asked the teacher students to write, explain and answer to different tasks. The subjects of the research, the students, interpreted the objectives from their framework as primary school teacher students and other frameworks which are unknown to me. This problem of the communication has been the key argument in deciding the research topics, thus, I am well aware of the situation. Knowing this, the objectives have been left free to choose. Most of the research data is in the form of neutral written texts concerning different learning subjects. In interpreting the data I have been as neutral as possible. As a researcher I am also aware of the fact that the context in which the students constructed the data is complex and not known by the researcher, who knows only the context of the education. I am also aware that the subjects were not always interested in writing the required texts. Thus several methods in collecting data have been used.
3.7 Analysis of data

All data in the form of written texts were transcribed completely by the researcher and a secretary working at the Department of Applied Education at that time. The students sent their narratives in an electrical form to the researcher. The transcriptions were loaded onto ATLAS-ti software for making the organization and deep analysis of the qualitative data easier.

Discourse analysis requires a particular orientation to texts, a particular frame of mind. It is important to develop a sense of what is involved before one even looks at the data. Potential importance is the absence, of “what is not there”. Paying attention to the absences opens up a variety of possibilities for the discourse analyst. Discourse analysis requires an ability to examine discourse creatively in all of its multifarious aspects and an open-mindedness to entertain multiple possibilities. (Wood and Kroger 2000, 91.) In this study of explanations of physics phenomena, the orientation, the frame of mind came from the context of the study, from physics education. The frame was thus connected to the concepts used or not used in physics. The analysis was started by reading through the texts carefully. Reading itself involves interpretation. Thus interpretation guides to further analysis.

Discourse analysis is primarily an analysis that is carried out by using words, that is, discursively, rather than by using numbers or quantitative techniques. Categorization is not included in the discourse analysis (Wood and Kroger 2000). In this study the distribution of certain features of explanations across various participants, was also under interest and consequently some level of quantitative aspects have been included. This was not the primary concern of the analysis but one interesting part as an indicator of the influence of the instruction. Discourse analysts avoid quantification in the form of significance testing of analytical claims, but as also Wood and Kroger (2000, 138) point out, they may use quantification in description or in the coding for selection prior to analysis the way it was used also in this study. Both numerical and non-numerical expressions are used to describe patterns, but no statistical tests are reported to support the descriptions.

After reading the narratives the view point of facts or themes was applied which means that facts or themes were searched. In the analysis of the narratives the paradigmatic knowledge is applied, when the data was graded and categorized. At first, the focus was on what the
students had told about their education. The analysis of the narratives was made by directing attention to the categorization of the narratives. But depending on the categories that are used, the coding may involve varying degrees of interpretation. The way that material was interpreted and coded in this study is not predetermined, that is, the interpretation and the coding are guided by the narratives. The way of telling, the style, was at first not under consideration. The analysis has two levels: the past year and the narrative. The past year is more interesting from the view point of the research questions. Narrative is dependent on the context but it is also very personal. Students are bound in time between their memories in time and the present moment. Narrative as a small life-story demands the truth in attitudes from the writer in telling the story.

Secondly, in the narrative analysis the focus is in producing a new story from the narratives in the data. In the narrative analysis the narrative cognition is applied by making more synthesis than differentiation to categories. The researcher combines texts, interprets and constructs, based on the original texts which means that the final inquiry text is a construction by the researcher and in this sense fictional.

As a teacher and a researcher I found the changes interesting, but I also found it interesting how the story was told, therefore the border between search of the fact and research of the talk was not wide. There is not just one way to read the stories. I have not read by applying any specific ways to read, not by knowing beforehand what is coming. On the contrary, my reading approach was an inspired way to read, a way where I hoped to discover something new and even to change after the reading and interpretation.

An analysis can be arranged according to empirical findings as it has been done in the frame of the context in this study. The data coding based on the data and the approach to the data analysis in every case was inductive which is typical for naturalistic inquiry. This means that all the units of texts, patterns and themes, which offered something "sensible" in terms of the study aims, have been coded; all descriptive themes in data were identified and given their own codes. Accordingly, through several phases of coding and interpretation the final categorization was formed. For the categorization the separate codes were grouped in respect of the properties of the code from the viewpoint of each research question. The categorization scheme is
reminiscent of the approach of typologies, in which the different types of data are divided according to some aspects during the analysis. The nature of the categories and the different patterns are interpreted through typologies.

The final phase of the data analysis focuses on the interpretation of the data. The findings of the data are understood, explained and compared with theories and empirical studies to reveal the core components of this study. Based on the data interpretations the new links and suggestions for the theories are established.

3.8 Summary of the methodological solutions

The empirical study was conducted by using the case study strategy. Accordingly, the study design and the qualitative research orientation were applied and appropriate data collection methods were tried to attempt. To summarize, the research process in this study is presented in Table 3.

The methodological solutions are principally similar in every research topics. The main difference occurs in the context. In the first research area the interest is in physics and mainly in arguments, and in the second area in the whole education and in a wider context. The empirical research results are presented in the next chapters. The results are presented in two parts, each subpart of the study in its own context. This is because the aim of the study is to understand the world from two different viewpoints. The conclusion using both phenomena (language in explanations and thoughts in narratives) are established at the end of the data presentations in a separate chapter.
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<td>written explanations in physics will provide data of the language which students use</td>
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<td>3. How are the students’ views of science and of science instruction related to the knowledge types that the students use?</td>
<td>the above mentioned data sources and methods are used further</td>
<td>the combination of the two case studies gives further information about the relations between views and knowledge</td>
</tr>
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4 Students’ explanations in physics phenomena

When considering the relation between primary school teacher students and science, i.e. students’ views of science, students’ understanding of some physics topics, and especially how they express their understanding is under consideration. The phenomenon under consideration is the discourse used by the students in the context of physics. It connects the ideas of the students and the science knowledge. The interpretation of the students’ language is based on physics concepts, the use of these concepts and my own physics knowledge. The purpose of the data analysis is to find qualitative differences or equalities in the students’ explanations, even though little attention is paid to the numbers of the justifications.

4.1 Questions and explanations

The physics questions dealt with mechanics (gravity), thermodynamics (heat transfer), optics (refraction and scatter) and electricity (magnetic field and electric field). Twelve of the seventeen students answered the questions both before and after the instruction period. Three students answered only once, and two of the students in the education didn’t answer the questionnaire.

Weightless astronaut

Why is the astronaut in the satellite flying round the Earth weightless?

a) The gravitation (veroimuus in Finnish) does not influence on him anymore.

b) The gravitations of the Earth and the Moon cancel out each other.

c) The gravitations of the Earth and the Sun cancel out each other.

d) The astronaut is not weightless.

The correct answer is the item d) and its physics explanation is the following: Neither the astronaut nor the satellite is weightless, the influence of the gravitation is not noticed, because both are in the falling motion due to the gravitation. The motion is difficult to
understand as a falling motion, because the distance to the Earth is the same the whole time. This is due to the fact that also the satellite moves in the direction of the Earth’s surface with the same velocity, and the Earth’s surface moves away in the same velocity than the satellite falls towards the Earth. (Mäkelä and Suvanto 1984.)

The students connected the astronaut’s weightlessness in most cases to gravitation as in the following discourse, B refers to the explanations in the beginning of the physics course and P8 refers to the student (person number eight).

The astronaut always weighs something. Also when he is floating in the space he weighs something, but the gravitation (painovoima) is not so strong that he “could be in place”. BP8

“The astronaut always weighs something” can be interpreted to express the concrete weight people have and measure. It is not seen to contain the existence of the gravitation. According to the student’s interpretation the astronaut is “floating” in the space. In the question the issue is about flying of the satellite. Floating indicates to the visual image people have about the motion in the space. Does the student think that floating and flying are synonyms? Probably s/he would understand the difference if it was asked. The student speaks about the astronaut’s floating, not that the satellite floats or that the astronaut is inside the satellite. S/he has not considered the problem in the present context, but has spoken generally about floating in the space. S/he does not discuss the motion of the satellite. The image or the preconception of people floating in the space has guided the thinking. The student states that the gravitation is not strong enough. S/he refers to the change of the gravitation in the space, but s/he does not mention which gravitation s/he means. Probably the student means the gravitation of the Earth only. “Enough” seems to mean the distance being long enough to decrease the gravitation. The student sees the opposition of the flying to be “could be in place”. S/he says that when the gravitation is strong enough, the astronaut could be in place. The student thinks that only the gravitation of the Earth is essential in the space. And s/he does not understand or at least think immediately that the gravitation can generally be due to other objects in the space, too. This kind of discourse analysis could give detailed knowledge about students’ understanding of the phenomena. However, that was not the aim of this study. Thus, it is enough at this stage to describe the explanations by using a broader line by seeing the explanations
as a whole and consider the concepts which the students used. The
language used by the primary school teacher students in the physics
explanations has no characteristic form, which could be interpreted to
belong just to teacher students’ culture.

Explanations for the “weightless astronaut” problem connect the
gravitation to the weightlessness, but the language which is used can,
as a whole (connecting floating to the weightlessness) not be seen
following the physics explanation.

The astronaut has still the same weight, but the pressure in the
space is different, because of that the astronaut is floating in the
shuttle. There is no gravitation (painovoima). BP11
Gravitations (vetovoimia), also of the Earth, influence on the
astronaut, because in another case the satellite would float. EP17

E refers to the explanation at the end of the physics course. Even
though physics concepts the gravitation, the floating and the pressure
were used, these explanations have the form which does not exactly
fit into the physics explanation. The concepts were not used precise
enough in order to make the physics explanation. The explanations
rather resemble daily life reasoning used by most people in everyday
situations.

Most of the explanations concerning the weight of the astronaut
were, however, somewhere between daily life reasoning and physics
(scientific) explanation.

The astronaut is so far from the Earth, that the gravitation
(vetovoima) of the Earth does not influence anymore. BP7
The gravitation (vetovoima) of the Earth does not reach outside
our atmosphere. EP6

These explanations include the fact that gravitation is dependent on the
distance, but the students have not understood the phenomena quite
right. They also stated that the Earth’s gravitation has no influence in
space or outside the atmosphere; there is no gravitation in space; in space
there is a weightless place; the attraction force of the Moon is weak; g is
no more the Earth’s attraction force but another attraction force.

Another type of describing the weightlessness-phenomenon by the
students was a way that sounded like physics explanation, but was
expressed by using sentences that sounded like daily talk.

The astronaut always weighs something. Also when he is floating in
the space he weighs something, but the gravitation (painovoima)
is not so strong that he “could be in place”. BP14
The weight is a different thing from the mass. Even if the gravitation (vetovoima) of the Earth doesn’t influence so much anymore, there are other forces in the space which influence – the astronaut is not weightless. EP11

The statement about weightlessness is right, but the other sentences are not precise enough to be taken quite as physical statements.

Two of the students used the physics concepts quite in the right way, but did not explain the phenomenon right.

The gravitation law is valid also in the space. BP15

The satellite is in the space just under the influence of the Earth’s gravitation, because it orbits the Earth, then a small gravitation influences on the astronaut. EP14

Teacher students did not use the concept gravitation (graviaatio) because in Finnish there are two acceptable concepts to be used instead of it: “vetovoima” (general concept) and “painovoima” (gravitation connected to the Earth). In translations the Finnish words are shown in parenthesis. Every explanation (21) included gravitation in the form of “vetovoima” or “painovoima”. The argument that gravitation does not exist outside the atmosphere is a misconception. None of the students tried to explain the influence of the two motions, which are essential in the situation. Some students had the misunderstanding that gravitation would not influence in the space. All students had limited understanding of the phenomena. The concepts which students used were real scientific concepts but the explanations were mostly incorrect. It must be noticed that the physical sounding explanation does not mean that the explanation or even the answer is correct. On the other hand, the daily life explanation could be accepted as a correct answer. At this stage of the research the knowledge level of the students was not under consideration. Both right and wrong answers were analysed in the same way in order to find out the type of language or knowledge, which the students used or showed.

The question concerning the weightlessness of an astronaut belongs to the subjects that have been discussed already at the fifth or sixth grade at the comprehensive school. The phenomenon appears also in the school textbooks. In this study it is interpreted that gravitation seems to be understood during the school instruction because the explanations at the beginning of the physics course were at the same level than after the physics course. The subject had not been discussed during the science education with all the first year primary school
teacher students. However, the role of the falling motion was not understood. The reader must be reminded that the topic is indeed difficult to understand exactly.

**Lighter feeling?**

<table>
<thead>
<tr>
<th>Where would it be more advantageous to weigh oneself, on the shore or on the mountain, if one wanted the weight to be the lowest?</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) on the shore</td>
</tr>
<tr>
<td>b) on the mountain</td>
</tr>
<tr>
<td>c) there is no difference.</td>
</tr>
</tbody>
</table>

B) is the correct answer. Gravitation depends on the masses and on the distance between the pulling objects. When climbing the mountain the distance from the centre of the Earth increases and the gravitation decreases. The decrease in the weight, however, is very small. For example, on the top of Mount Everest the weight of a hundred-Kilo-person is 399 grams less than on the Earth’s level. (Mäkelä and Suvanto 1984.)

Among the 25 explanations the air pressure, the mass, the gravitation, and the value of g is smaller, were used as reasons for the weight difference.

*The air pressure is higher than down in the valley.* BP11

*There the mass is smaller.* EP13

Half of the explanations (12) were like physics explanations and the other half (12) represented another kind of descriptions mainly used in daily life. Daily life descriptions are for example.

*The pressure decreases on the mountain, thus by going up I am “lighter” on the mountain.* EP3

*The person is farther away from the Earth’s core.* EP4

*The Earth’s gravitation (vetovoima) has the same influence both on the mountain and on the shore, thus no difference was measured.* BP3

The following discourses are almost physical explanations.

*On the mountain the Earth’s gravitation (vetovoima) is smaller.* BP7

*The weight g is smaller on the mountain, because the Earth’s gravitation (vetovoima) there...less further away from the Earth’s core, the mass does not change.* EP17
The weight \( g = mg \). On the mountain the value of \( g \) is smaller – the Earth’s gravitation (vetovoima) is not so big because the person is further away from the Earth’s core. EP12

Many students were of the opinion that there is no difference in the weight. The reason why so many explanations to the weight-problem where, however, quite correct is probably because this question is closer to everyday life than the astronaut-question and is thus discussed more in daily life. Anyway, also in this question the physics, which was used, was not exactly correct. Students mixed the influence of the pressure and the gravitation. They did not understand correctly or at least did not express the difference between the mass, the weighth and the force (painovoima).

Although the air is lighter/less dense on the mountain it is not the reason for the decrease of the weight. But the connection between the mountain and the lightness of air is understandable, because the difficulty to breath in the mountains is generally known. The familiar explanation is tight together with the question, although it is not the correct explanation in this context. All students explained their choice with acceptable physics concepts, but the explanations were not correct. The explanation “the density of the air does not influence the weight” is correct, but the influence of gravitation has not yet been taken into account. “A person weighs the same everywhere in the Globus” might be the answer to the other question. The explanations for this phenomenon were very short which I interpret to be due to the illusion of an easy question.

Is the time sufficient?

The car is driving the one hundred kilometer drive from Helsinki to Hämeenlinna. During the first 50 kilometres the velocity is 40 km/h because of the traffic jams. What should the velocity be during the last part of the drive in order to have the mean velocity of 80 km/h?

a) 120 km/h
b) 160 km/h
c) 200 km/h
d) is not possible.

The correct answer is d). The average speed on the journey from Helsinki to Hämeenlinna would be 80 km/h if the journey was driven
in one hour and 15 minutes. That time the car, however, used already for the first 50 kilometres with the speed of 40 km/h. The time has come to an end, and it is not possible anymore to reach the required average speed, even if the light velocity was used during the rest of the journey. (Mäkelä and Suvanto 1984.)

Most of the answers (18) were very short. The primary school teacher students used average speed, calculated the speed by the aid of the two given velocities, summarized the velocities, guessed or tried to use logical reasoning. In this question it was typical that the students did not explain, they simply repeated the question.

The mean velocity is 80 km/h. BP1

In this type of the students’ explanations the question, its part or some of the items are only repeated. The reasoning by average speed is used without checking the possibility of the answer.

By summarizing mean velocities and by dividing by two the mean velocity will be 80 km/h. EP13

or

One can summarize 40 km/h and 120 km/h, because half of the drive has been driven with both these velocities. EP7

Physical sounding expressions, with some colloquial language, were also used.

That the mean velocity in 100-km-drive would be 80 km/h, the drive could take only about 1.25h. The traveller has already used this time during the first 50 km. EP17

Some explanations used formulas:

\[ \text{velocity} = \frac{\text{distance}}{\text{by time}} \text{ for the first 50 km used time} = \frac{\text{distance}}{\text{by velocity whole distance} = 50 \text{ km}/40\text{km/h} = 1.25 h \text{ 80 km/h} = 100\text{km/x} \times x = 100\text{km}/80 \text{ km/h Thus that time, which should be used for 100 km (thus mean velocity could be 80 km/h) goes already for the first 50 km } EP8 \]

In general, the explanations for the drive problem were at very low level. The students tried to use mathematical formulas without succeeding in it. Four students understood that it was impossible to reach the required result and these students had also used physics’ tools in their explanations. It seems that when the teacher students saw numbers they tried to calculate something and forgot entirely the verbal explanations. The short verbal explanations were mainly common sense ways to explain. One of the explanations was rather illogical, but also logical reasoning was used. During the physics course
of Science and Technology Education formulas are very seldom used at the lectures. Students do not calculate anything during the classes. Lectures concern the understanding of the phenomena and the verbal explanations. Calculations are not used at the primary level either.

**Open door**

What happens for the room temperature, when the door of the refrigerator is opened?

a) the room temperature does not change
b) the room gets warmer the whole time
c) the room cools off the whole time
d) at first the room cools of, then it gets warmer.

The answer d) corresponds best to the reality. At first the temperature in the room decreases a little as the temperature difference between the refrigerator and the room levels off. The cooling off of the refrigerator is, however, only motion of the heat from one place to another, in this case from the refrigerator into the room. Moving from colder to warmer, demands energy from another source, which usually comes from the electricity net, and this energy finally changes to heat. (Mäkelä and Suvanto 1984.)

Students gave 24 explanations to the refrigerator question. Refrigerator question was explained by non-physical concepts. Students used words like level off, flow, cool, air comes.

*The temperature tends to level off. More warm air. Bp1*

*Because cooler air comes from the refrigerator. Ep13*

*I suppose that there are normal radiators in the room which warm from their part as more cold air flows into the room. Ep16*

These explanations represent daily life descriptions. Most (19) of the explanations were of this kind.

Also physical concepts were used.

*The room gets cool quickly near the refrigerator, but as the refrigerator must produce more energy, it stays cool, the "machine" starts to produce heat and thus warms the room. Ep3*

But, however, the explanations are everyday descriptions although physics concepts are used. Some explanations sound physical although colloquial ways to explain are clearly used.
At first the room is cooling off when cold air from the refrigerator flows into the room but when the engine of the refrigerator works it starts to produce warm air. BP13

A physics explanation is seen only in one of the explanations. At first cold air flows from the refrigerator, but because the consumption is bigger the engine of the refrigerator must work more effectively, thus heat energy is released. BP3

As in the preceding problems also these explanations are correct or incorrect independent on the expression type. Most of the answers were incorrect but it must be noticed that the subject is quite difficult to understand. Also, it is seldom explained to primary school teacher students or in the physics courses at school. The explanations were very approximate. One student tried to explain the working principle of the refrigerator, one student used the concept of energy in the explanation and one student used the concept of work. It seems that the answers rise mainly from the everyday experiences. The discussion is superficial and the situation is not considered deeper: does the room stay colder, where the heat comes from and so on.

**Boiling**

When one brews a pot of tea, the quickest way to boil the water is to use the highest possible power at once. But what is the most economical way to do it?

- a) to use the lowest power so that water just starts to boil
- b) to use the highest power
- c) the way has no influence to the total consumption of electricity.

The answer b) corresponds to the most economical way. When water is being heated up, it starts to deliver heat to the environment, mainly by evaporation and radiation. The longer the heating lasts, the more heat is lost and the more electricity is used. Thus the water should always be heated up on the highest power. Time and money is saved. (Mäkelä and Suvanto 1984.)

Boiling is a typical topic in daily life and it is probably discussed in some context during the schooling, or in the context of cooking. Probably because of that, in 18 out of the 20 explanations descriptions of daily life type were used.
The consumption of electricity is constant the whole time and water warms up slowly. With the highest power more energy is used than necessary. BP11
One gets water come to the boil quickly – the plate doesn’t have to be on for a long time. BP12
The faster water boils, the less electricity is consumed. BP8

Two of the explanations were something between daily sounding descriptions and a physical way to explain.

On the highest power the plate consumes less time and less current compared to heating up on lower power for a long time. EP7
The faster water boils, the less current is consumed. EP14

The students reasoned their answers by the even consumption of electricity, with the power, the time, the energy or the speed. No physics explanations were noticed. The dependencies between boiling, energy and time were not seen to be important. Some students were of the opinion that it does not matter how the boiling occurs. Nobody mentioned the heat transfer, the evaporation or the radiation. These concepts are, however, discussed quite deeply during the physics course. Heat is also one of the topics discussed at the primary school. The use of daily descriptions shows the practical meaning of the problem – saving of the energy – but not, how it is done. This problem in daily life is, however, one of the actual subjects in discussions concerning the saving of the energy as also in discussions concerning sustainable development.

Mirror

The landscape reflecting from the calm water surface is a little bit darker and upside down compared to the original landscape. Is it the same otherwise?

a) yes
b) no.

The reflected landscape is the same when it is viewed from the water surface. The landscape seems different in the mirror image, when it is considered from another direction. The viewing point of the mirror image is actually lower than the observer. (Mäkelä and Suvanto 1984.)

Again, most of the explanations (16 of 19) were formulated by using very general daily ways of explaining such as

Water surface is like a mirror. BP2
Image is a mirror image. EP14
It is a little bit “longer” than the original landscape. The image
“gets longer” when it is reflected off the water. EP3

Physics sounding explanations used refraction.

Light beam refracts towards the normal when it hits the water.
EP16

Longer, water refracts. EP17

One explanation is seen to be between a daily way to explain and
physics reasoning.

Refracts a little bit on the boundary. Changes. BP1

In most cases the teacher students equated the water surface with a
mirror but did not explain how the “mirror” in question would work.
One student thought that the image changes but could not explain
how. Another student wrote that the image does not change but did
not justify the statement. Many students were of the opinion that
the image is either longer, shorter or smaller. Nobody noticed that
the image could be somehow different from the original landscape.
In general the explanations did not actually answer to the question.
Reflection had been already mentioned in the question but, however,
most of the students only mentioned it without explaining its nature.

Some students probably did not understand the difference between
reflection and refraction. It is also possible that the explanations were
going shorter than in the preceding questions because of tiredness
of answering as the questionnaire continued. Refraction belongs to
the school curriculum at the primary level and is also discussed in the
teacher education during a compulsory course for all primary school
teacher students.

In this mirror question it had been necessary to enclose a picture
of the situation which was under consideration, and thus to specify
the situation. It was designed to be included in the questionnaire of
the study, but it was left outside by my own mistake. Even though
the question was not correctly written, it was possible to consider
from the point of view of this study the language which students used
concerning reflection.
Shadow

What is the colour of the shadow which the Sun makes on the snow?

a) black  
b) grey  
c) red  
d) blue.

The shadow is blue. The shadow of the Sun on the snow is not black, because the light scattered from the atmosphere reflects on the snow. In the scattered light the amount of the blue wavelengths is bigger than that of the red wavelengths, thus snow which reflects all wavelengths in the same way looks blue in the shadow places. (Mäkelä and Suvanto 1984.)

The students produced 17 answers to this question. The explanations were very different. Some students gave very general explanations.

Light does not go through the object, which forms the shadow. BP1

Quite often explanations were wrong.

The snow does not reflect back. EP13

The snow absorbs the black colour of the shadow. EP5

One student said that s/he answered what s/he had seen. Nine of the explanations were given by using no physics way to reason. Everyday or common sense ways with physics concepts were also used in reasoning.

The sunlight has all wavelengths. Because the snow reflects white light, the counter colour of white is black. BP8

Black colour. BP8

The shadow is always black, because colours (reflection) do not exist without light. BP6

Physics ways to explain were also used.

The light with the longer wavelength (400) is filtered away, and the light with the shorter wavelength, blue 700, reflects to the snow behind the object. EP6

The snow reflects a little bit the blue of the sky and looks blue. EP4

The wavelength of the light reflected off the snow in the blue region. EP16

Again the explanations were very confusing and in many cases they said nothing about the real situation. It seems as if the students had tried
to make the situation more complex than it really is. The students did not make connections with their observations in everyday life. In this topic the students’ understanding, according to the explanations, was very low. However, due to my tacit knowledge I assume that they would probably have understood the physics behind the question if it had been discussed in the physics course. The problem probably is that they are not able to transfer their physics knowledge to the everyday situation.

A clever knob

On the top of the antenna of the car radio there is a knob, because
a) it makes the audibility better
b) a sharp top would be dangerous
c) it prevents the antenna from vibrations in the blowing wind.

The right answer is a). A moving car is exposed to rather strong rubbing charges. The charge density is highest at the corners and on the top of the object. A big charge can be concentrated on a sharp point, e.g. on the point of an antenna with the result that the intensity of the electric field due to the charge is enough to ionize the air molecules. The so-called corona discharges, currents coming from top, are possible to occur. In the dark these discharges can be seen as light phenomenon, for example on the tops of planes in an aeroplane. The car radio emits very weak electromagnetic oscillations by the aid of its antenna, and there are strong cracklings in emitter due to the corona discharges. In this case the solution to the problem is easy: No discharges will develop and the top effect can be avoided by formulating the top to be spherical. (Mäkelä and Suvanto 1984.)

The students produced only 13 explanations to this question and all these explanations used everyday ways to explain

- There is more mass in the knob, thus waves can reach it easier than the thin whip. BP6
- Experience has shown that the audibility of the radio is better when a person holds the antenna. BP2
- It makes the antenna heavier, thus the antenna can not swing so much. BP13

For this question none of the students gave a correct explanation or used even the right concepts. The students talked about the mass, the surface area, easy catching of waves, the heaviness and the balance of
the antenna. The explanations were everyday language but also quite thoughtless. As we know electricity is one of the most misunderstood topics in physics thus the poor explanations could be understood in that context. Discharges are less discussed during the teacher education and do not belong to the curriculum at the primary level. The subject has indeed been one of the most difficult ones in this study.

**Compass**

Orienteers know that they cannot trust the compass under the power lines. If the power line is in the east-west direction, as shown in the figure, then the needle of the compass shows under the lines to

a) the north
b) the south
c) the east
d) the west
e) anywhere.

The correct answer is e). Magnetic field which can turn the needle of the compass is formed around the electrical lines. The needle turns away from the direction of the magnetic field of the Earth. If the current flows from east to west, a magnetic field directed to the south is born under the electrical lines. The needle points to the south. But electricity is transferred in lines as alternative current, which changes its direction 100 times in second. The direction of the magnetic field changes in the same beat. The needle of an ordinary compass is not able to follow the variations in the field so quickly, but is probably directing to a random direction. (Mäkelä and Suvanto 1984.)

The answers to the compass problem were more physical than to the questions discussed above. The total of 11 out of the 17 answers was physics ways to explain.

*Electricity causes a changing magnet field? The needle of the compass can point anywhere*, BP11
*The movement of the electric charge causes the movement of the magnetic compass needle*, BP8
*The moving (changing) electric field causes a changing magnet field. Thus, when the compass is under the electric line, the changing magnet field influences it, and the needle of the compass moves constantly*, EP8
The more commonsense way answers with physics concepts though, were also used.

- *It depends on which direction the compass point to. The direction changes.* BP1
- *It felt more natural than the east, the needle, however, on the direction of the line depending on “the electric magnet”* BP6

Entirely common sense descriptions are still correct:

- *Magnetic field mixes the compass.* EP4
- *Electrical lines cause the needle to get messed up.* BP16

The situation of using the compass under electrical lines has generally been discussed at school and in the physical education of the teacher education. Thus students know the situation either from everyday experience or from other instruction than physics including informal learning such as the Scouts. But that they could explain the reason quite well comes probably from the physics course of Science and Technology Education. In the preceding science education inside the teacher education electric and magnetic fields are not discussed.

The phenomena presented above are adopted from a book called “When is the Moon brightest?” It is written for ordinary people and the understanding of the phenomena should not demand expert knowledge. Some of the topics were very familiar to the students, but the questions in general differed from the exam questions at school or at the university.

### 4.2 The framework of categorization

Primary school teacher students justified their choices of the alternatives in the physics questions by using words, phrases or concepts which did not noticeably differ from the concepts of school books or the expressions used in everyday life and based on experiences. There were no specific ways or languages, which could be said to be constructed by this student group, in a sociocultural place of primary school teacher education, to explain the physics phenomena. No distinctive way in talk, in representations, which could reflect a special world, was not noticed either.

Most of the students connected things incorrectly and the logical reasoning, characteristic to physics, is absent. Explaining without observed understanding gives an impression that the precise
knowledge is not important. In some explanations students really tried to 1) explain the phenomenon, but some explanations were purely 2) tautological phrases, in some explanations 3) real concepts were used, but not explained and then there were rather 4) irrational explanations. All students in this study justified physics phenomena nearly in the same way. The understanding of the physics phenomena and concepts related to them were superficial. Especially the concepts related to each other, the force, the power or the gravitation were mixed in the language which they used. But as their discourse and representations were equal, we can draw conclusions that communication in their own community is probably successful. Problems may arise, when things are discussed with an expert, who uses the precise concepts and refers to the essential thing behind the phenomenon.

After having read the students’ explanations for the physics phenomena very carefully, I noticed that their knowledge represented factual knowledge. In the literature reasoning has been studied mainly in the framework of everyday-scientific knowledge. In this study the students used some kind of colloquial languages in their descriptions as also physics’ way and mixed different ways in explanations. These notions finally led to the categorization of the students’ explanations by the aid of definitions of everyday knowledge and scientific knowledge instead of the beforementioned categories. The term scientific is commonly used to denote a sphere of human activity characterized by special qualities: rationality, precision, formality, detachment, and objectivity. This view is broadly held in society at large, at schools, and even among some scientists themselves. The term everyday is commonly used to denote another, opposing set of qualities: improvisation, ambiguity, informality, engagement, and subjectivity. The presumed differences between scientific and everyday activity are often framed as sets of dichotomies: precise versus imprecise language, logical versus analogical reasoning, scepticism versus respect for authority, and so forth.

By everyday knowledge we mean common knowledge about natural phenomena acquired by most people in their daily life and in early schooling before coming to a more systemic study of science (Reif and Larkin 1991, 736) or everyday, colloquial language or common sense ways of talking and thinking (Leach and Scott 2000, 43). It is developed and reinforced after being brought up in a cultural group, learned and reinforced subconsciously through everyday communication. The
role of the cultural group is also within the description of life-world knowledge constructed by children talking together (Solomon 1993, 92; see also Ahtee 1998). We are socialised into this knowledge system which responds to everyday knowledge by daily use with familiar people. The explanations such as,

*The faster water boils, the less electricity is consumed. BP14*

*Water surface is like a mirror. BP1,*

serve as good examples of the everyday communication based knowledge. Knowledge in everyday life is acquired through interaction with the world and other people. Past experiences and local knowledge about specific contexts are generally quite adequate for such commonly required predictions and explanations as in the phenomena of the boiling of water. In everyday life, things tend to require an explanation when there is something about them that needs to be done. Real life responds to personal need, and problem solving is judged successful when it delivers a positive outcome: better control or a desired change.

By scientific knowledge we mean predominantly knowledge which is encompassed by the present-day physical sciences (Reif and Larkin 1991, 787), which in this study is seen for example in the following student’s description.

*The gravitation law is valid also in the space. BP4*

Scientific knowledge is developed and validated by scientific communities and it means a more formalized way of talking and thinking than everyday knowledge (Leach and Scott 2000, 43). Science is “artificial” and is in several respects distinctly different from the “natural” knowledge of everyday life (Reif and Larkin 1991, 736). The central goal of science is to achieve optimal prediction and explanation by devising special theoretical knowledge which parsimoniously permits inferences about the largest possible number of observable phenomena. Optimal prediction and explanation imposes very stringent requirements. There is a need for great generality, and correspondingly long inference chains, to ensure that a very small number of theoretical premises can lead to predictions about very many phenomena. Consistency must be maintained throughout the entire scientific knowledge structure to guarantee that different arguments will not lead to contradictory predictions. All scientific knowledge needs to be precisely specified so that unambiguous predictions can be made to any desired degree of precision.
In these definitions everyday knowledge is jointed to a culture group, in which the user of the knowledge has grown up. The working of the knowledge is tested in social communication. Thus, it is understandable that the use of everyday knowledge does not influence any problems in a common culture not even in the case of science. Problems arise when everyday knowledge and scientific knowledge encounter.

A knowledge domain is a collection of declarative and procedural knowledge useful for attaining some particular goals. The knowledge domains of physics and of everyday knowledge are examples of such domains. The specific knowledge of a domain consists of the concepts used in this domain, the relations among them, and the methods for dealing with them. Specific knowledge of physics consists of the concepts, principles, and methods useful in physics. Similarly, specific everyday knowledge consists of the factual knowledge and methods useful for coping with daily life. Knowledge of the goals and useful cognition in a domain is called metaknowledge. In everyday knowledge it is important to pursue the sub goal of predicting, and sometimes of explaining, and commonly observed physical and biological phenomena such as

The air pressure is higher (on the mountain) than down in the valley. BP11

in the students’ explanations. It is useful to predict that a parked car is going to roll downhill if its brakes fail, or to explain why pressing a switch does not produce the expected light in a lamp (Reif and Larkin 1991, 738). Various kinds of knowledge can be used appropriately in different contexts founded on daily experience, common sense, or tradition like description.

The features of everyday knowledge and scientific knowledge based on Reif and Larkin (1991) as also on Leach and Scott (2000) are shown in Figure 5.
A three-way relationship thus exists between the phenomena, the everyday ways of talking about the phenomenon, and the scientific description (Leach and Scott 2000). A great deal of research has been carried out internationally on the ways that students typically explain natural phenomena (see, e.g. Duit 2004) and how these so-called alternative conceptions develop over time (Driver et al. 1994). During the last decade this topic has been less often under consideration, though. Learning science involves the reaching of understanding and the ability to use the conceptual tools of the scientific community. In this process the learner is engaged in making sense of the scientific view, and this learning is carried out against a backdrop of existing everyday ways of thinking about the phenomena under scrutiny.
Everyday thinking is the basis for scientific thinking. No one is born as a scientist but develops everyday thoughts and everyday knowledge in social contexts. Everyday thinking involves meaningful views about reality, which helps people to solve everyday problems. Everyday thinking does not work in science and everyday knowledge is not a valid evaluation basis for science. (see Sormunen 2004.)

Besides everyday knowledge and scientific knowledge also school science knowledge has been considered in the literature. Pupils’ knowledge is characterized as follows; non-formal, tied to everyday life, near culture, background knowledge, beliefs, naïve theories, tied to the history of the pupil, novice knowledge (Enkenberg 1990). School knowledge is conceptual, formal, non-context, and it delivers scientific knowledge, metaphors, compromises and expert knowledge whereas scientific knowledge is conceptual, formal, structural, explicit, improving, expert knowledge, theories, models and explanations. Pupils’ knowledge is transmitted in plays, in games, by experience, in circle of friends, through the media and through action. School science is transmitted through printed learning material, teachers’ talk and through the school as a social organisation. School science is different from real-life problem solving, also on grounds of the criterion for judging the value or correctness of an idea: the approval of an authority, in the shape and form of the teacher and the textbook (Claxton 1991, 55). The final area in which school science and real-life problem solving might be said to differ, is in the social context which surrounds both of them. In everyday world, learning is often, though not always, a social activity. Social groups are constituted on the basis of mutual interests or of pre-existing relationships where mutual support can be expected to exist. School science, on the other hand, has been seen as rather a solitary enterprise, with students making their own discoveries and developing their understanding of the presented concepts to the best of their knowledge. (Claxton 1991, 55-56.)

The students’ explanations in this study do not exactly correspond to the definition of scientific knowledge the way Reif and Larkin (1991) have defined it, as the knowledge predominantly encompassed by present-day-physical sciences. They also do not correspond to scientific knowledge of Leach and Scott (2000) as a more formalized way of talking and thinking. Rather, the explanations represent some knowledge between scientific and everyday knowledge and could be seen as school science knowledge. In a student’s explanation,
Light beam refracts, when it hits the water, to the direction of the surfaces normal. EP16
real scientific concepts are used, the statement is quite right, but it does not answer the question. Instead of scientific knowledge I prefer to speak of school knowledge.

Because everyday understanding is usually acquired through experience and implicit learning, students often use familiarity as a criterion for understanding – rather than the scientific criterion which requires demonstrating the ability to make many diverse inferences. Thus they claim that they understand Newton’s basic mechanics principle (F=ma) because they can state it and have studied it – although they may have little ability to apply it in solving various problems (Reif and Larkin 1991, 744). Same reasoning is noticed in one of the primary school teacher students’ explanation.

In the space there exist other masses, which attract the astronaut
\[ g=mg \] – no more, the Earth’s gravitation but gravitation of some other mass. EP12

The student has learned the principle but can not use it in quite a correct and exact way in the situation under consideration. Students often use everyday reasoning (direct perception and commonsense) to move forward with explanations which lack the basis in scientific premises.

The shadow is always black, because colours (reflection) do not come into existence. BP6

As I was reading the explanations it became evident to me that the everyday knowledge and the scientific knowledge/school knowledge were insufficient to account for the variations in students’ discourses. Some of the explanations resembled everyday knowledge even though they had been expressed by using scientific knowledge. Some of the explanations sounded like scientific knowledge, but the knowledge, which was used, was, however, everyday knowledge. The framework of the explanations was thus expanded to four different categories. The basic building blocks of knowledge in any domain are concepts and relations between these concepts, words or other symbols are used to denote these concepts. Conceptual knowledge must also be appropriately organized to facilitate the tasks needed to attain the goals of the domain (Reif and Larkin 1991, 745). But the different goals and requirements of everyday life and science imply corresponding differences in the structure of knowledge in these domains. Learning science involves coming to understand, and having the ability to use
the conceptual tools of the scientific community. In this process the learner is engaged in making sense of the scientific views, and this learning is carried out against a backdrop of existing everyday ways of thinking about the phenomena under scrutiny. This kind of perspective on science learning, which draws attention to the active role of the learner, and the interplay between the existing and the "new" knowledge, is often referred to as a constructivist view of learning. The learning demand can relate to various kinds of differences (Leach and Scott 2000, 45): differences in the conceptual tools used; differences which relate to the basic assumptions about the nature of the world (ontological assumptions); and differences which relate to the nature of the knowledge being used (epistemological assumptions).

The action of drinking juice through a straw, in the preceding example, is described in terms of "sucking" in everyday situations; for example, children from an early age are able to respond to parents' requests to "suck quietly" as they drink through a straw. For a parent and a child, little difficulty is involved in establishing a shared understanding of what is meant when the child is exposed to this kind of talk from birth. However, potential difficulties in establishing a shared understanding do arise when a child faces these familiar events in school science lessons. It is here, in the classroom, that the teacher faces the challenge of introducing students to the scientific ways of interpreting and explaining the phenomena, which the students already think about in their own everyday ways. A three-way relationship thus exists between the phenomena, the everyday ways of talking about the specific phenomenon, and the scientific description. The learning demand in this situation for an individual learner might involve: using the concept of "air pressure" rather than that of "sucking" (a conceptual demand); coming to accept that air is a substantial matter which can cause large pressures (an ontological demand); and appreciating that the concept of air pressure is generalizable and can therefore be used to explain a whole range of different phenomena (an epistemological demand). (Leach and Scott 2000, 42-45.)

In this study the demands are taken into account in categorization. Table 4 shows the categorization of students’ explanations for the physics questions. The concepts relating to the phenomena and those, which students used, are shown in the Table. The ontological and epistemological demands are on the background of the categorization, but can not be seen as clearly as the concepts used.
The students could not specify the concepts explicitly and thus were unable to identify them properly in a typical situation which agrees with the observations of Reif and Larkin (1991, 747). The primary school teacher students used concepts very broadly. It can not be said that their concepts were wrong, but nor were they used quite correctly. Their concepts, even that they were scientific had everyday meaning. Everyday concepts were used in scientific explanations, and scientific concepts were used in everyday explanation. In the categories between those the concepts resembled more everyday concepts even though as words they were scientific concepts. In everyday life the connections between concepts and their references are ordinarily not specified with great precision and concepts need not necessarily be related to observable phenomena. The concepts which the students used in everyday explanations were mainly related to the phenomenon, but they were not always the most essential concepts. By contrast, the scientific goal of parsimonious and extensive predictive power imposes exacting requirements on scientific concepts. Such concepts must be precisely defined and should lead to no inconsistencies. Scientific concepts can be freely invented, if that seems useful, without any regard to common sense or other preconceptions. Many scientific concepts need to be very general in nature to permit parsimonious predictions. But despite of their generality, they must be unambiguously interpretable in any specific instance, even if the reasoning chain is long and indirect. All concepts must ultimately be connected to observations; otherwise they are scientifically meaningless since they are irrelevant to the central scientific goal of predicting and explaining observable phenomena. (Reif and Larkin 1991, 746.) The concepts may specify either entities such as the “sun” and generic entities such as “particle” or properties associated with them such as “mass” and “acceleration”. Students in science classes often take the liberty to use special words, like “energy”, without attaching clear scientific meanings to them.
<table>
<thead>
<tr>
<th>physics subject and concepts</th>
<th>physical argument</th>
<th>physical sounding arguments constructed with everyday concepts</th>
<th>everyday arguments with physical concepts</th>
<th>everyday arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>weightless astronaut</td>
<td>gravitation, law, the Earth's gravitation</td>
<td>forces</td>
<td>The Earth's gravitation, atmosphere, planets, weightlessness, gravitation of other masses</td>
<td>pressure, floating</td>
</tr>
<tr>
<td>gravitation: fall motion, velocity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lighter feeling gravitation</td>
<td>value of g, the Earth's gravitation</td>
<td></td>
<td></td>
<td>air pressure, mass, the Earth's gravitation, friction of air, height difference</td>
</tr>
<tr>
<td>does the distance end?</td>
<td>time (used already), time (has gone already)</td>
<td>mean velocity is velocity at the beginning added with end velocity and divided by two</td>
<td></td>
<td>mean velocity, summarize</td>
</tr>
<tr>
<td>velocity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>door open transfer of heat, energy changes</td>
<td>flows cold air, engine of refrigerator must work more effectively</td>
<td>engine works, compressor works with higher power, engine warms</td>
<td>difference balances, machine warms, refrigerator must produce more energy, machine works lost</td>
<td>more warm air, cold air sinks, comes colder air, diffusion, temperature decreases, radiator warm, balances, goes warm-comes cold, flows cold air, cools</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>boiling transfer of heat, energy, power</td>
<td></td>
<td></td>
<td>power-time, time-electricity</td>
<td>boiling needs specific power, time-energy, waist of energy, water boils fast, time-less electricity, power-time</td>
</tr>
<tr>
<td>mirror refraction</td>
<td>reflects, water refracts, refracts</td>
<td></td>
<td></td>
<td>plane mirror, mirror, longer, shorter, smaller, distorted</td>
</tr>
<tr>
<td>shadow scattering, reflection</td>
<td>reflection, filtering</td>
<td>reflects, refraction</td>
<td>transmission, reflection (bejastra), absorption</td>
<td></td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>antenna charge density, corona discharge</td>
<td></td>
<td></td>
<td>mass, catching on, surface area, heaviness, balance, voice</td>
<td></td>
</tr>
<tr>
<td>compass electric field, magnetic field</td>
<td>motion of magnetic field, changing magnetic field, electricity moves in specific direction, motion of charges, current, electromagnetic field</td>
<td>electromagnet</td>
<td>magnetic field</td>
<td></td>
</tr>
</tbody>
</table>

Students tend to bring everyday goal conceptions into the scientific domain, with the result that they often pursue inappropriate goals in their study of science. Thus most students do not share scientists’ focus on making inferences and transcending existing knowledge. Students often perceive no need for formal methods, or find such methods difficult to implement, but instead use informal methods from daily life (Reif and Larkin 1991, 751). For example, students often answer questions about the motion of objects, or forces on them, on the basis of what seems sensible without any formal reasoning based on Newton’s basic mechanics principle, F=ma, which they have learned. From students explanations it can be seen that they don’t perceive to use exact concepts, rather they use concepts broadly.

In this study the primary school teacher students used explanations where they claimed that they had understood something because they could relate to it by reasonable arguments, to common or other familiar knowledge. This observation agrees with that of Reif and Larkin (1991, 741) where understanding can be demonstrated by explanations that merely identify a perceived causative agent or note some connections among relevant features. Such explanations are not only common among children, but also among adults. Students tend
to accept commonsense notions. They find it difficult to believe that these may be scientifically meaningless or useless. Conversely, they find it difficult to appreciate that artificially invented concepts can be highly meaningful and useful. (Reif and Larkin 1991, 740.)

During Science and Technology Education physics is taught for understanding. Formulas are not used and mainly the subjects significant for the primary level are discussed. Science courses taught at schools do not often adequately foster the scientific goal of understanding, or may inadvertently even pervert it. Many courses encourage and reward the memorization of knowledge, rather than the ability to make diverse inferences leading to scientific understanding. The courses may train students more in the performance of fairly routine tasks than in the inferences needed to deal with unfamiliar situations. They often teach skills of formal symbol manipulation, but leave students unable to make qualitative inferences which would demonstrate more flexible understanding. (Reif and Larkin 1991, 744.)

4.3 The nature of the knowledge in different physics topics

In this study it is also investigated whether there are any differences between the students’ explanations in different physics topics. How the students use the concepts and link different things together is not seen clearly in their answers. Probably the students’ knowledge of science forms both true formal school education and everyday life. The students used everyday knowledge, which had been worked out in normal life, and they often mixed knowledge. Due to the formal education the students had adopted scientific concepts, which they used either correctly or incorrectly. But, at the same time they used everyday knowledge which works well in daily life. Also, everyday knowledge can produce right or wrong understanding.

In my study the first two physics questions concerned mechanics, the next two questions thermodynamics, after that, two questions dealt with light or waves and finally there were two questions about electricity. The frequencies of the explanations of different type are shown in Table 5.
Table 5. Different kind of knowledge found in the physics explanations (at the beginning/at the end).

<table>
<thead>
<tr>
<th>subject of the question</th>
<th>everyday knowledge</th>
<th>everyday knowledge expressed by using scientific concepts</th>
<th>scientific sounding knowledge expressed by using everyday knowledge</th>
<th>scientific knowledge</th>
<th>quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>astronaut/ gravity</td>
<td>2 (1/1)</td>
<td>16 (8/8)</td>
<td>2 (1/1)</td>
<td>2 (1/1)</td>
<td>22</td>
</tr>
<tr>
<td>mountain/ gravity</td>
<td>12 (5/7)</td>
<td>0</td>
<td>0</td>
<td>12 (7/5)</td>
<td>24</td>
</tr>
<tr>
<td>car/velocity</td>
<td>13 (5/8)</td>
<td>0</td>
<td>1 (1/0)</td>
<td>4 (2/2)</td>
<td>18</td>
</tr>
<tr>
<td>refrigerator/ heat transfer</td>
<td>18 (11/7)</td>
<td>2 (0/2)</td>
<td>2 (1/1)</td>
<td>1 (1/0)</td>
<td>23</td>
</tr>
<tr>
<td>boiling/heat transfer</td>
<td>18 (11/7)</td>
<td>2 (0/2)</td>
<td>0</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>mirror/ refraction</td>
<td>16 (8/8)</td>
<td>1 (1/0)</td>
<td>0</td>
<td>2 (0/2)</td>
<td>19</td>
</tr>
<tr>
<td>snow/scatter</td>
<td>9 (4/5)</td>
<td>5 (4/1)</td>
<td>0</td>
<td>3 (0/3)</td>
<td>17</td>
</tr>
<tr>
<td>antenna/charge density</td>
<td>13 (5/8)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>compass/ electric field, magnetic field</td>
<td>4 (3/1)</td>
<td>2 (2/0)</td>
<td>0</td>
<td>11 (4/7)</td>
<td>17</td>
</tr>
<tr>
<td>quantity</td>
<td>105</td>
<td>28</td>
<td>5</td>
<td>35</td>
<td>873</td>
</tr>
</tbody>
</table>

By comparing the explanations of the phenomena, it is noticed that the questions concerning mechanics (astronaut and mountain) were explained by using more scientific or scientific sounding knowledge than everyday knowledge, and the questions concerning thermodynamics (refrigerator and boiling) were explained by using more everyday knowledge than scientific knowledge. Why is it so? The topics in mechanics, which were asked in this study, have been discussed more exactly than the topics of thermodynamics during Science and Technology Education in its physics course “From Falling Objects to Quarks”. Thus students have adopted more precise knowledge of the subject. That may be one of the reasons for the better conceptual knowledge in mechanics. On the other hand, the topics of thermodynamics and the discussion of them are closer to people in everyday life than mechanics topics. Thus, these phenomena have
been explained by using experience. But the mechanics topics are not
discussed to the same extent in daily life, even though mechanics is
present there. Mechanics is not as concrete a topic as thermodynamics.
Thus pre-existing conceptions are not so strong in mechanics and
those concepts which have been learned in physics course are used in
explanations. But students have not learned to connect these concepts
correctly. For example, the Earth’s gravitation has been discussed a
lot and has been connected with demonstrations during the physics
course, which probably have influenced the students. Gravitation is a
more familiar concept than, for example, energy or force, which were
not used correctly in the students’ explanations. It must be noted,
that everyday knowledge was not necessarily the wrong way to explain
a phenomenon, or the explanations using scientific knowledge were
not always the right way to do it. The students might also explain
phenomena quite right by using only everyday knowledge and wrong
by using scientific knowledge.

In optics domain (mirror and shadow) the students used everyday
knowledge and in electricity domain (antenna and compass) both
everyday and scientific knowledge. Light is normally very near to
everyday life and is therefore easily explained by common sense
knowledge. From the point of view of the development of the
instruction it is interesting to note that even I, the teacher of the physics
course, who has specialized in optics, couldn’t make the students learn
the simplest laws of optics. In some way this could be clarified by
notions that many traditional teacher education activities suit poorly
with the world images which teacher students hold (Wubbels 1992).
These world images cannot often very well be influenced by logical
language, the type of language usually applied in teacher education
programs. In the study of Wubbels the problem is approached from
the viewpoint of brain research. It must also be reminded the reader
that the questions were quite difficult to explain also for those who had
studied physics. To the electricity question (compass), which had been
discussed during the physics course the students answered quite well
even by using scientific concepts. Scientific knowledge was used even
in the questions concerning everyday phenomena familiar to students.
The other electricity question (antenna), not included to the course,
was answered by using everyday knowledge.
The students' understanding of a topic was fragmented, so they did not have a scientist's theory-like view of the world which supports Palmer's (1999) finding. DiSessa has, according to Palmer (1999), named these fragments as p-prims (phenomenological primitives) and they can be understood as simple abstractions from common experiences. A particular problem context activates a particular p-prim and that determines the type of explanation the student gives. The context of the task influences the inference pattern one employs. Probably the language used by the teacher has not changed from one topic to another despite of the specialization. The differences cannot be explained totally by means of the observations of Wubbels concerning the role of teacher's specialization. According to Palmer (1999) knowledge system is weakly organized so that the students' justifications typically lack depth and their responses can often appear to be ad hoc in nature. Students possess pieces of knowledge, which Minstrell (according to Palmer 1999) calls facets, and which are closely related to a particular context of a problem. Explanations in this study show that the students do not have deep understanding of the subject. Their knowledge is fragmented. The students made their reasoning by using superficial knowledge. For the most part the students did not notice the essential thing related to the task. They liked to reason the tasks by means of words, which were quite right, but not precisely. Anyway the students tried to explain the phenomena and only few times they wrote that it does not matter what the answer is. The superficiality of their reasoning, however, reveals that it is not only about knowing or not knowing, but also that it has not been important for the students to explain.

It can be said that the primary school teacher students do not have good scientific knowledge concerning physics phenomena. School science knowledge is the actual aim in science education at schools and in primary school teacher education. Knowledge, which students in this study showed, has more of the properties of school science than that of scientific knowledge. A primary school teacher student does not belong to the science community during her/his studies. S/he studies science in their own department not in subject departments together with physics students. Thus her/his community is the community of educational science. Thus, it is not realistic to set the aim at adopting the scientific knowledge transmitted through scientific community.
Science and Technology Education is subject studies during which students do not familiarize themselves with scientific articles. Thus the adequate knowledge is school science knowledge, which is between scientific and everyday knowledge. The students’ conceptions concerning the nature of science or the scientific knowledge were not found in the data of their explanations. It could be carefully estimated, because of the shortness of the answers, that the conception of the knowledge is closer to the traditional factual knowledge than to the understanding of entities.

The categorization found in my study differs a little from the following categorization by Greenwood and Scribner-MacLean (1997): explanations that illustrated that teachers had an understanding of the science idea were often drawn from observations of everyday life; deficient explanations contained terms which were used inappropriately; explanations which were little more than a collection of sounding words; explanations based on a belief and not understanding. But in the main features there is the same idea. Greenwood and Scribner-MacLean have studied elementary teachers’ explanations in the context of physics and especially of optics. They have noticed that even the subject knowledge of the teachers increased during the period of further education, explanations given by the teachers gave another picture of the degree of the learning. The explanations, which the teachers gave, were firstly categorized in their study as follows: illustrating some or no understanding of the science idea or having an understanding of the science idea at a level that could help the teacher to explore the phenomenon with children at an elementary level. In detailed analysis the beforementioned categories were found. Consequently, this study agrees with the results concerning the physics explanations used by the teachers in the inquiry of Greenwood and Scribner-MacLean.

Some of the teacher students’ explanations in this study combine both scientific knowledge and everyday knowledge. Students develop their own ideas and beliefs about natural phenomena even before they have formally been taught science. When students are learning about science, they interpret any new information in the light of these existing ideas and beliefs, which then become modified or revised. Scientific sounding explanations formed by everyday knowledge, and everyday knowledge formed by scientific knowledge are probably formed
in this way. It has been suggested that alternative conceptions and scientifically acceptable knowledge represent two completely separate ways of thinking with very little, if any, connection between them. On the other hand, along with alternative conceptions, many students can have “anchoring conceptions” which are described as “an intuitive knowledge structure that is in rough agreement with accepted physical theory, and which could be linked to their alternative conceptions via a series of related examples” (Hawkins and Pea 1987). In any particular content area, students may have alternative conceptions as well as other ideas that are more scientifically acceptable (Palmer 1999). This kind of alternative conceptions were not found in this study whereas alternative ideas were found. In every category some ideas could be accepted scientifically. The conceptions, which the students used, were quite scientific, but they were not necessarily the right ones for the context. The explanations connected to the anchored conceptions, even that they represent everyday knowledge, show that the students have understood the phenomenon. Sometimes students may learn the right thinking and understanding but not the right scientific concepts (Aho et al 1993). The explanations in this study were mostly explanations, but the students have repeated the question only by using other words. The students seemed to believe that they had given explanations for the phenomena although they really didn’t give any. Their metacognitive knowledge is undeveloped in the domain under consideration (Keinonen and Lehtelä 2004) and is not significantly better than that of 13-year-old pupils (Lehtelä 2001).

The finding that the knowledge type the students used depends upon the question asked agrees with the finding that 15-year-old students are using a mixture of school knowledge which depends upon what their science teacher has discussed with them, and everyday knowledge that emanates from the outside of school as Solomon et al (1996) have observed with British students. Life-world knowledge is a social construction like local culture which provides ample of opportunities for personal choice (Solomon et al. 1996). Its “cafeteria” character allows students to use their own cognitive preferences in selecting what may seem to be the “right” answer to a question on which they have had no formal guidance. The science education of most students in this study is nearly the same as that of the British pupils, who have studied physics at school for some years. But, the students in this study
participated also university physics courses. Thus, it could be expected them to be closer to the world of the scientific reasoning. The results demand to think more exactly about the contents and methods of the physics instruction.

There are equalities between the interpretations described above and that of the inquiry concerning the reasoning in the context of the text describing scientists’ work by Leach et al. (2000). It might appear that studies which suggest that there are common features in the reasoning used by large numbers of students in populations of given ages assume that an individual’s reasoning patterns are stable and consistent over a range of contexts (Leach et al. 2000). However, it is possible that the complexity of individual students’ reasoning in different contexts is masked by commonalities in patterns of reasoning at the population level. As regards the views of individual students: does an individual student use the same sort of reasoning about science and scientific knowledge across a broad range of contexts in a consistent and stable way, or is her/his reasoning better characterised as being situated and contextual as Leach et al. (2000) ask? According to them the answer to this question is very significant for science education. One interpretation of the findings is that students typically draw upon more than one form of reasoning when responding to the questions. This might be predicted from the situated perspectives on learning. Students also select at least some of the fixed response statements randomly. It seems that students choose the statements without using hardly any critical judgement which, as did even the science students at a fairly advanced stage in their education in the study of Leach et al. (2000).

The total amount of the explanations decreased when the questionnaire continued. Probably the students got tired towards the end of the questionnaire. Anyway, the type of knowledge was found even from the decreasing explanations. The answer to the first research question “What kind of knowledge do the students use in explaining physical phenomena?” has been found: The students use mostly everyday knowledge, which is described above. The answer to the second research question “What kind of differences are there in the explanations of different topics of physics?” has also shown above. To find the answer to the third research question “How have the explanations changed during the instruction period?” we will have to compare the explanations before and after the instruction.
4.4 Change in students’ knowledge

The students’ explanations before and after the instruction period were compared. To understand how the explanations of an individual student altered the change in the reasoning categories between the beginning and the end of the physics course was clarified from the explanations. The reader must be reminded that the change under consideration is not a conceptual change. The students’ conceptions are not investigated exactly. In Table 6 the change in the students’ knowledge type is presented. If the explanation changed one step in the order used in the Table 4, from everyday knowledge towards the scientific knowledge the student got one + -sign. If there was a change to the other direction towards everyday knowledge the student got - sign and thus lost one + -sign in net change.

Table 6. The change in students’ knowledge type

<table>
<thead>
<tr>
<th>student</th>
<th>net positive changes</th>
<th>number of explanations with positive change</th>
</tr>
</thead>
<tbody>
<tr>
<td>P14</td>
<td>++++++++</td>
<td>3</td>
</tr>
<tr>
<td>P16</td>
<td>++++++++</td>
<td>3</td>
</tr>
<tr>
<td>P17</td>
<td>+++++++</td>
<td>1</td>
</tr>
<tr>
<td>P11</td>
<td>+++++++</td>
<td>3</td>
</tr>
<tr>
<td>P5</td>
<td>+++++</td>
<td>0</td>
</tr>
<tr>
<td>P6</td>
<td>+++++</td>
<td>2</td>
</tr>
<tr>
<td>P8</td>
<td>+++++</td>
<td>1</td>
</tr>
<tr>
<td>P3</td>
<td>++</td>
<td>1</td>
</tr>
<tr>
<td>P7</td>
<td>++</td>
<td>0</td>
</tr>
<tr>
<td>P13</td>
<td>++</td>
<td>2</td>
</tr>
<tr>
<td>P12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>P4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The student 14 changed in her/his explanations towards more scientific way to explain in eleven cases and the student P16 in ten questions, respectively. Also the students P17, P11, P5 and P6 used more scientific explanations after the instruction. However, all these students used also everyday knowledge after the instruction in some questions. Thus, the net change was not remarkable. The students P15, P1, P2, P9 and P10 filled only one of the physics explanations questionnaire, so the change can not be determined.
The instruction has had no remarkable influence to the knowledge type of the students. There are surely a lot of things which could be changed by instruction, but anyway, it seems also that the knowledge learned in the informal context and everyday life is very stable. The finding agrees partly with the findings of Greenwood and Schribner-MacLean (1997) among elementary school teachers. They noticed that in the post test analysis after the instruction only two categories of responses existed: responses based on observations of relevant experiences and responses drawn from workshop experiences which partially provided evidence but did not fully explain the statement. Thus, in their study the type of reasoning decreased from four to two types. Students in this study, may not have understood exactly when they were using scientific when everyday knowledge, because they had also negative changes. Now the last research question in this problem area has been answered, too.

4.5 Concluding remarks concerning students' knowledge type

It is common for even toddlers to call for and offer explanations of natural phenomena as part of their interaction with the natural world. How do plants grow? Why is it snowing? Where does water come from? How do people see in space? Such questions are asked when the questioners' concepts are insufficiently developed to be generalized to the understanding of the present case, and the questioner is motivated to further understand. "Accountings" for such phenomena are common in everyday conversation.

In this study the primary school teacher students explained physics phenomena with different knowledge types: everyday knowledge, everyday knowledge with scientific concepts, scientific sounding knowledge with everyday concepts, and scientific knowledge. Every student used all different ways to explain. The students' reasoning was superficial including fact knowledge, and even many scientific explanations were wrong. The concepts relating to the task were not always correct. But, however, the explanations were mainly partly correct. Different topics stimulated different types of knowledge. Mechanics phenomena were often explained by scientific knowledge
and thermodynamics questions were explained by everyday knowledge. One feature of explanatory accounts, whether in everyday conversation or science, is that they each have a certain precision. An explanation is expressed with some degree of exactitude, with the tacit assumption that the explanation is sufficient for the purposes for which the inquirer asked the question. This purpose-relative feature of explanations is called its pragmatic precision by Hawkins and Pea (1987). It seems that the students had better reasoning when the question was near daily life. Explanations and conclusions need only to meet standards of pragmatic precision in everyday life that is, to be precise enough for the purposes of the inquirer. The students used that precision which is adequate for them. The notion of explanatory precision interacts with the notion of a problem niche. Each “culture” or community has a set of problems that seems to bind the types of problems considered at a particular time. There is a tacit limit of precision for explanations judged acceptable by a specific community of inquirers that is directly tied up with the state of a problem niche. Thinking and explanation are adaptive to the circumstances to which they are directed. Changes in the problem niche may change the requirements for sufficient precision as former conceptual schemes become incapable of covering more challenging problem situations.

Between the students no difference in the nature of explanations were observed. If a primary school teacher student explained well one question, did s/he not necessarily do in other questions as well. No specific coherence between the students and their responses was found. Possibly the teacher students have different experiences from different topics of everyday living and also different mental images from different topics due to the school science. The two main origins of experience impinging on the individual are the first-hand impressions of sensory input from the physical world, and the second-hand relaying of experience from the culture which the individual inhabits. Representations from direct experience and from cultural mediation are described as sources which can be independent of one another but which can also overlap. The third source of knowledge representation is the formal education.

Understanding the nature and also the source of differences in how scientists and non-scientists think can indicate efforts in science education to engage students in authentic scientific practices,
including reasoning practices. To understand differences in how people reason it is necessary to understand differences in their contexts for reasoning, recognizing, for instance, how scientists’ thinking benefits from their membership in the cultural institution of science in ways that non-scientists’ thinking does not. Students and scientists apply different criteria when reasoning because they are members of different communities of practice. Educational strategies to enhance students’ scientific reasoning should focus on the influence that classroom community practices can have on individual development. (Hogan and Maglienti 2001.)

The students’ knowledge was a surprise for me. In some cases I had underestimated (compass) and in some cases (mirror) overestimated their knowledge and the use of concept. This agrees with the finding of Rovick et al. (1999) that instructors are poor judges of what the first year students know. In their inquiry the instructors tended to both underestimate and overestimate the students’ knowledge. In their study, despite considerable experience with the student population entering their courses, instructors did not have an accurate understanding of the knowledge base and capabilities of these students. The students knew more of some things and less of others than the instructors expected. Generally, the teachers’ estimate of the students’ factual knowledge is better than their assessment of the students’ abilities to apply these facts in solving problems. However, if application skills are a better estimate of true understanding, as many educators think, faculty assumptions about what students know are an inadequate guide for planning courses.

Some researchers have explained the shortcomings in scientific reasoning as having less to do with the domain-general processes of hypothetico deductive thought and have associated developmental constraints on reflective abilities, and more to do with the presence or absence of domain-specific knowledge that guides experimental explorations. Research on scientific reasoning is extended by Hogan and Maglienti (2001) to link cognitive perspectives on what reasoning processes look like to sociocultural perspectives on where reasoning practices come from, in other words, from the cultural practices of various groups. People seem to possess both informal heuristics for thinking and more formal rules of logic, and they use whichever suits for a particular purpose. They are pragmatic in their deployment of skills from different cognitive repertoires, depending on perceived
contextual demands. Hogan and Maglienti have concluded that the responses of students differed from responses of scientists, with the major difference being the groups’ relative emphasis on criteria of empirical consistency or plausibility of the conclusions. They argued that the sources of the groups’ differing epistemic criteria rest in their different spheres of cultural practice. Epistemological criteria are one’s philosophical assumptions, beliefs, and theories about the nature and limits of knowledge and its acquisition. Developmental capabilities as they appear are not so much as cultural preferences that lie at the root of reasoning differences between groups such as students and scientists.

In one tradition of science education, as Warren et al. (2001, 530) state, misconceptions research holds that students’ everyday ideas are strongly held, may interfere with learning, and need to be replaced with correct conceptions. They continue that studies in this tradition argue that misconceptions, e.g., about force and motion, arise from students’ prior learning, often from their day-to-day interaction with the physical world. Thus everyday experience is viewed as a principal source of the educational problem. A second tradition of inquiry in science education takes a different view. It focuses on understanding the productive conceptual, metarepresentational, linguistic, experiential, and epistemological resources students have for advancing their understanding of scientific ideas. (Warren et al. 2001, 531.)

In their study Warren et al. (2001) do not assume a simple isomorphism between what children do and what scientists do; rather, their work views the relationship as a complex one and with a variety of forms: similarity, difference, complementarity and generalization. They point out the importance of taking seriously the ideas and ways of talking and knowing that children from diverse communities bring to science. Often, the ways of talking, making arguments, and developing theories which are thought to constitute science are seen as distinct from the linguistic and social practices used in everyday life. Warren et al. (2001) have found that a narrow view of what constitutes scientific ways of knowing can lead to a narrow range of responses to some children’s ideas, which in turn can lead to limited participation by these children in science. Likewise, a limited view of the meaning-making afforded by some children’s everyday language can lead to mismeasurements of the depth and complexity of their sense-making in
science. Warren et al. (2001) think that it is crucial that the diverse ideas and ways of talking and knowing of all children should be brought into contact with each other as well as with standardly recognized views and modes of organizing explanations and arguments. They see the contact among different perspectives as a creative critical process in which diverse ways with words and ways of seeing are probed, challenged, and perhaps even transformed for the benefit of all students.

Science instruction depends also on the development of hypothetico-deductive reasoning ability (Kwon and Lawson 2000). The acquisition of a theoretical concept such as air pressure depends in part on the development of hypothetico-deductive reasoning ability because this ability is needed to construct arguments used to reject intuitively derived misconceptions (e.g. suction) prior to acquiring theoretically derived scientific concepts, i.e., undergo the necessary conceptual change. Conceptual change is one of the key factors in physics education in the teacher education as also at the primary level (Hau-Nuutinen 2005). It must be reminded that in this study the change is not a conceptual change because the conceptions are not clearly investigated.

Although students in this study performed well in the Science and Technology courses, it was noticed that reasoning skills were, however, poor. The results of this study have influenced partly to the decision that in the future every course in Science and Technology Education is going to have own exam to ensure the understanding of the discipline to some extent. During the courses I had got the impression that the students had well acquired the knowledge of the subject under consideration. The quality of the explanations was thus unexpected. As Antoine Saint-Exupéry describes

"Indeed, as I learned, there were on the planet where the little prince lived as on all planets good plants and bad plants. In consequence, there were good seeds from good plants, and bad seeds from bad plants. But seeds are invisible."
5 Students’ experiences

The second problem area of this study dealing with the students’ views of science concerns the science education experiences of the primary school teacher students found in their narratives. In the narratives I searched for things which are significant for the students and tried to understand what these things tell about the students’ relation to science.

Seventeen primary school teacher students were asked to write a one-page-story/narrative about their Science and Technology studies after the education had been conducted in May 2000. All grades for the courses had already been given, thus, the students were free to express their opinions about the education. The aim of the open instructions for writing was to find out which things the students themselves highlighted. I read the narratives carefully in order to find out the students’ ideas. The narratives were then coded by the aid of the Atlas-ti program for the qualitative analysis.

5.1 General description of the structure of narratives

Every story had a title constructed by the student. The titles varied telling about the students’ attitudes towards the science studies or science. The titles can be categorized into four groups. Five of the titles are very factual.

Science, technology and society P7
Science and technology studying P8
Report of the science (luonnontieto) and technology courses P13
Science and technology P10
Science and technology – Conclusion P2

These titles reflect the cognitive grip to science studies and the reporting way to write about the studies. Science studies are regarded mainly as a neutral way to absorb knowledge. One of the students called the studies “luonnontieto” as science is called at primary school.

Two of the students highlighted the reflective aim of the story.

Reflection about science and technology studying P4
End reflection P15
These students reflected Science and Technology Education as if assessing the entity.

Two other students had a more personal view to reflection and they reflected their own learning process, or at least saw the writing as self-reflection.

Self-reflection about the science and technology – course P12
Considerations of my own learning process P16

The writers here are active learners who have learned something during the education. They refer to the changes, to learning, in their own minds or thoughts.

Five of the students pointed out their own person during the studies more than the students mentioned before.

Me as a science student P5
Me as a science learner P9
My science and technology studies in the academic year P1
My ST-studies in the academic year P11
Me and science-minor subject P14

The students highlighted their own personal role in the studies. They had experienced some changes in their own behaviour, thoughts, attitudes, knowledge or in something else. They pointed out their own person as a whole.

Two of the titles expressed more feelings.

My feelings about the science and technology – education P17
Pleasure and responsibility – my relation to science and science studies/teaching P6

The last title is much more emotional and takes also into account the behaviour of the people in connection with nature. It also points out the student’s own relation to both science and science instruction. And it takes into account the student’s role as well as the teacher’s role.

The titles did not express the background of the students or their thoughts at the beginning or at the end of the education. The students did not tell about the challenges, about their learning, or the final conclusion either as being positive or negative. The titles were neutral except the last one which took a stance on the subject and gave an impression that it is following some consideration about pleasure and responsibility.

The students’ writings in this study were mostly seen as narratives which were understood as a spoken or written text giving an account of an event/action or series of events/actions, chronologically connected, according to Czarniawska (2004, 17). In this study the event under
consideration was Science and Technology Education and the common properties in narratives were mainly the descriptions about the education in the sense of the principal property of narratives. According to Bruner (1990, 43) this property is inherent sequentiality: a narrative is composed of a unique sequence of events, mental states, happenings involving human beings as characters or actors. All narratives are stories about a specific past event, and they have common properties. Traditionally a story has been viewed as being less or narrower than a narrative, but also narratives are purely chronological accounts and stories are emplotted narratives. A narrative has an abstract, orientation (time, place), action (sequence of events), evaluation, resolution (what finally happened) and coda (return to the present). In this sense the writings in this study were broadly interpreted to be narratives. Mostly the narratives in this study started from the expectations and from the first course and then narrated each course in their chronological order. Then the students came to some conclusion concerning assessment or learning and their present situation. Also, an orientation part is often included. In this study narratives were seen as chronological telling, without having a clear plot. The students’ writings follow this kind of telling. A story includes more emotions or imaginative properties, which was not found in the writings of this study.

5.2 What do the students highlight?

The codes (themes) found in the students’ narratives and the responding frequencies are shown in the Table 7 for every student. Many of the descriptions could be categorized to more than one code.

Student P17 has not written the narrative and students P9 and P10 have not explained the physics phenomena. The total of 399 descriptions, were found in the narratives in 26 different codes. Most of the descriptions, were coded as assessment of the courses and secondly, the students told about changes in their thoughts or behaviour. Thirdly, the students reflected their learning. Because these codes were the largest groups, it seems that the aim of the narrative to reflect the education has been achieved. Thus the answer to the first research question in this part of the study “What do the students highlight in the education?” has been answered.
Table 7. Codes (themes) found in the narratives

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5.3 How do the students describe science education?

The students mostly documented education (62 descriptions) by describing the good or bad sides of the education. Typical descriptions in the assessment code were:

Newspaper project was good and taught to read papers “from the viewpoint of science” P1
The course of geography was a real pearl P1
Chemistry was interesting P2
STS-course did not inspire me P2
The last part of the education was meaningful, because sciences were tied with a part of technology. P3
It is good that in science courses things were dealt by experimenting, testing and observing. P7
I got most clues for the teaching from the courses of physics and chemistry, but from the courses of geography and biology I got most knowledge. As a whole thinking of this arrangement it suited for me, thus I got teaching hints from those areas, which, to my opinion, have been most difficult to teach by illustrating. P8
I would have desired more concrete teaching hints and ideas for the primary school. P14

The students were mostly satisfied with the education. They respected especially the hints for the teaching and found the education interesting. Mostly the education had been either difficult enough or easy enough. Different students felt different parts of the education in a different way.

Secondly, the students described the changes in their own action or thoughts (42 descriptions). These descriptions were connected to the students themselves, while the above mentioned assessment code was connected to the courses, teachers and the content of the education. Typical descriptions for the change were.

I still like to learn "small" things like during the upper secondary school time. P2
Then I started to think scientific subjects as topics supporting each other. This conception has still been reinforced in my vocational studies, where the teaching has pointed out the connections between things. Also in minor studies I could have widened further my scientific view. P3
I have noticed how important it is to be able to search knowledge. P3
I feel that I have got certainty to my own teaching P6
Immediately at the beginning of the education a motivation to study science aroused in me P7
I think more in the context of investigations. P10
Bias knowledge, which has reinforced during the course, sometimes even entirely changed P13

The students clearly described changes in their thoughts or actions. Most of the students got more interested in science during the
education than they had been before the education. The students told that they were no more afraid of the science teaching, thus expressing that they had earlier been afraid of it. One of the students still liked learning details, facts, as s/he had done earlier in the upper secondary school. And one of the students told that her/his scientific view had expanded. The changes, which students expressed, mostly concerned thoughts on science and on science teaching.

The students reflected their own action 35 times.
\[
I \text{ am more ready and more unbiased from the viewpoint of my own teaching. I believe that I can pass my own enthusiasm and interest to my future pupils. P3}
\]
\[
I \text{ am still proud of the washing machine, which we constructed, and how I (our group) was able to familiarize myself with the project P6}
\]
\[
\text{Science courses, which served experiences, have contributed to the modelling of a wholly new conception of learning – Each time I had to acknowledge that studying is very inspiring and fun. P12}
\]
\[
I \text{ feel that the image, which I had about a science teacher, has gone through a change during the education: The teacher does not have to be a besserwisser and infallible, but first of all s/he has to be interested in the subjects, which s/he teaches. P16}
\]

The reflections concerned mainly the own teaching profession, and the changes in the ability to teach science. Also, the thoughts of science have changed and the students expressed that they had got a lot for themselves. The reflection was basically always positive and could also be called self-reflection.

Descriptions in the code benefit (24 descriptions) were as follows.
\[
\text{To my opinion after this education I will have revised the basics widely, and I have learned to join sciences to things, which I would not have considered to join them to earlier. P3}
\]
\[
\text{Little by little during the spring I was developing a feeling that I myself could arrange science teaching with the ways in the question. P7}
\]
\[
\text{The education has been rewarding during the advanced practise, when environment and science studies were my didactic subject, and cells, digestion and circulation topics were to be taught P9}
\]
Education like this, benefits the teaching of several subjects.
P10
This education gives a stronger basis to teach sciences at the
comprehensive school and maybe it pushes to advanced studies
in these subjects. P13
The benefits were mainly seen to be directed for the teaching abilities.
When the students’ teacher training focused in science and as it was
coming quite soon after the education, these students highlighted
the benefit of the education for teaching. The benefits concerned the
students’ own profession, the students did not highlight, for example,
scientific literacy, or their abilities to manage in their everyday life in
the future or their role as citizens in the society.
As much as the students described benefits they also described the
whole education (24 descriptions).
As a whole science and technology education was interesting P1
This was a very compact package and thus I had to deal with
things the whole time. P5
As the timetable of the science education was, unfortunately,
as it was, too much information came perhaps in too short
time. P8
In these courses the especially good thing was, that besides the
"strong" theory package, it was possibly to familiarize oneself
with things by different practices. P13
To my opinion the entity is many-sided and comprehensive. P16
The students were satisfied with the entity and then described its
good sides. They acknowledged specially the multifaceted teaching
methods. Also the content was acknowledged. All these students under
consideration completed their Science and Technology Education. It
also expresses their satisfaction to the education as an entity.
Learning and teaching were both described 20 times by following
descriptions.
Laboratory work was instructive. P1 (learning)
Learning is dependent on own willingness and interest. P11
(learning)
I do not believe that a teacher can pour knowledge into my
head but I am an active searcher of the knowledge and I process
it. When I studied sciences the teachers gave me directions
and stimulus, which I myself have started to investigate. P3
(teaching)
It is true, that at school nowadays the teacher needs just subject knowledge and it can be insisted, that the content learned in the courses can easily be connected to the things learned earlier relating to teaching and learning strategies. P4 (teaching)

The students expressed their views of learning and teaching concerning mainly Science and Technology Education. The subjects were not considered widely. The descriptions were commenting by nature and concerned the students own learning.

The students described their background (16 descriptions) mainly by writing about their earlier interests.

…since my childhood I have been interested in nature and its different phenomena… P3
I have in fact always liked chemistry and geography. P10
Sciences have been my favourites since the primary school. P7

Almost all the students had been interested in science before the education. They told which subjects they had always liked. Some of them were very interested in the environment. These interests were mostly the reasons why they had chosen Science and Technology Education. Some of the students were not especially interested in science, but they were still satisfied that they had chosen these studies. Their upper secondary school studies in science had been very different. Some of the students had studied the minimum and some of them the widest range of courses.

The students described also their subject courses mainly positively. The chemistry course ‘From Methane to Macromolecules’ was described 14 times and mostly very positively.

Chemistry was interesting, but I had to study extra from upper secondary school books. P2
Especially chemistry practices were really interesting. It was nice to make aspirin! …it was so unbelievable, is it really so easy, is this really genuine aspirin… P14

Their descriptions of the physics course ‘From Falling Objects to Quarks’, and the geography course ‘Changing Globe’ scored the second whereas the biology course ‘Processes and structures of life’ was less often described. Geography and physics were described 11 times.

Changing Globe—course was with its learning excursions a real experience and surely the interest of our teacher had influenced it P10
For example during the field work as part of geography I learned a lot of new things in two days and I could have listened to the teaching even longer. P7

Physics nearly caused me grey hair, fortunately we did not have to calculate. P1

Physics has always been and probably will be the most difficult subject for me. P4

It seems that the students highlighted more positive experiences than the negative ones. The more descriptions they wrote the better they had found the course. The chemistry course was found "to be a good review", "laboratory work was instructive", "interesting". The geography course was also found positively "a real pearl", "a real experience", "especially rewarding". Only one student said that "to my opinion also other subparts besides Finnish geography should have been emphasized".

The physics course was like chemistry "good review" and the students felt that they had got hints for teaching, "useful experiments". But many participants also disliked physics; "Physics nearly caused me grey hair", "I found physics as high-flown", "part of the content of the lectures do not belong to the primary school", "I was mostly afraid of the chemistry and physics before the education". The biology course was experienced to be "a lot of new knowledge and interesting things", "good content".

Technology relation was also described 14 times.

The course, in which we collected newspaper articles about science and technology opened my eyes to see how big a part science and technology govern in our society. P8

After the project had familiarized with industry, it is not a nut idea to widen one's own skills also there. P15

The students mainly told about the relation between technology and science as a new thing. They had not recognized earlier the role of the technology in the society. The change in their attitudes towards more positive attitudes expresses that before the education they had quite negative attitudes. The students also felt that science instruction can include technology.
The students described the environment (12 descriptions) very positively.

According to Finnish tradition nature means a lot to me. P3
I have learned to see sciences as a part of everyday life and to observe nature phenomena outside the study book from the own environment. When I earlier kept science studies and the enjoyment of nature as separate parts, I have now learned to join them together in a natural way – as a goal to embody the whole of the knowledge, attitudes and action related to the environment. P12

The descriptions concerned nature. One of the students had written many descriptions from the environment and they were very long compared to the other descriptions in general.

Sciences were described 11 times.
I believe that science is one of the thematic whole at school, which is closest to real life… P10
…all science subjects are exact… P11
…science as a part of everyday life… P12

Science descriptions concerned both sciences as a part of life and also as one of the teaching subjects. The students wrote of the change in their attitudes and in thinking about science toward more positive direction.

The first course ‘Science and Technology as a Knowledge and Action’ was found entirely positively (6 descriptions).
My opinion the whole education started well. P2
The beginning course gave a good general view of what was coming. P9

The STS-course was described 10 times. In the descriptions different opinions were expressed.

To my opinion Perlo project did not equal to its purpose, I don’t believe that Perlo could benefit from our investigations. Our subject, however, was interesting. P4
Perlo investigation deepened my conception on how science and technology go together in real life. P10

The last and largest course was found very confusing. The students wrote about the technology project (LEGOLogo-project) or about the industry project (Perlo-project) and less about the lectures of the course. Lectures had not impressed them as much as the projects.
Learning style and scientific knowledge were also considered (9 descriptions both).

My style to study is traditional, I want to use time for studying and I want to get the largest possible knowledge for myself. P3

To my opinion no other study method is as rewarding as when a real expert concretely shows things which s/he teaches and explains it at the same time. P15

The students valued the methods to study in different ways. Few of the students valued traditional methods whereas the majority of the students found more constructivist methods suitable. Scientific knowledge was seen in the same way ranging from remembering facts to changing knowledge (conceptual change).

It is necessary to remember a lot of different things and sometimes even very small details. P4

There are no answers to be found immediately for every question and for some questions the answers is never found. P16

Knowledge also changes continuously. P16

The choice of the education and the future were both described 8 times.

At first the time I heard of minor science studies in the students' info in the autumn. I got interested immediately, because sciences have been my favourites since primary school. P7

I have not planned to specialise in sciences and technology, this was extra minor studies for me. In the autumn I, however, noticed that it fits in my timetable and I decided to take it. P5

Mostly the students had been interested in science already before the education. It was the most general reason mentioned as the choice of the education. Some students chose the education without being especially interested, it fitted their program or they felt that it could be useful later in applying for a job.

This was certainly also a stepping-stone for advanced studies so last autumn I started the minor studies in geography and I will continue until subject studies. P1

I will probably do my master thesis in the field of science teaching and learning. P6

...I hope that I can benefit my pupils in the future from what I have learned. P11

The students expressed two kinds of future hopes. Some of them were so interested that they wanted to continue science or science teaching
and learning studies. Some others valued their acquired skills to teach science better in the future because of this education.

The students expressed directly what they had expected (7 descriptions).

...I expected interesting moments. P1
...I had expected that during the course we would deal with issues, which for example during the studies in the upper secondary school had been left for less attention, or which I did not understand at that time. P4
...When I took the courses I wanted to get more information about issues which belong to sciences and also hints for teaching, which I could use with my own pupils in the future. P8

The students expected content knowledge but also hints for teaching. One student also said that s/he wanted to satisfy her/his “science interests”. Hopes (6 descriptions) came very close to the expectations.

...if the entity were that it would respond the environment- and science studies at school. Then one could teach that subject and specialize in it. P1
Instead of Heureka-report (teaching project) it would have been nice to follow experts’ lessons (not in the training school) and report the teaching methods, teachers used, materials, structures of the lessons, observe pupils working etc. One could get a conception of the teaching of the subject from the viewpoint of the teacher as also from the pupil. P5

The students did not have many direct hopes and all of them were hints for the development of the education. Developmental ideas also concerned project works.

There were only 5 society descriptions.

The lessons gave useful information of the society. P1
In reading newspapers one felt, that almost every piece of news was connected to science in some way, but in the discussions together one noticed, that there were not many news concerning purely science. This tells something about our society. P15

The role of the society in science was quite a new issue for the students and they discovered the role mainly during the newspaper project. They wrote three times about this newspaper project.

It was nice to make a small investigation, in which one familiarized oneself with how science and technology are seen in the media. P2
... I learned to read newspapers in a wider context and to reflect news from the viewpoint of their background, and the choice of the issue. P15

The students seemed to like the newspaper project and the aim to encourage the reading seems to have been reached. Teaching project was described 4 times.

Teaching project was nice... P1

One of the absolute pearls of these courses was also the teaching period in Noljakka school, P15

Three of the descriptions were positive and one expressed the hope to exchange the project of one’s own teaching to the following of the teaching carried out by an expert. The second research question in this part of the study “How do the students describe education?” has now been clarified.

5.4 Student groups

The quantity of the descriptions of each student ranged from 16 to 35. According to the quantity of the descriptions the students can then be categorized into the following groups (Table 8).

<table>
<thead>
<tr>
<th>quantity of descriptions</th>
<th>quantity of students</th>
<th>students</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-20</td>
<td>4</td>
<td>P4, P9, P12, P16</td>
</tr>
<tr>
<td>21-25</td>
<td>5</td>
<td>P2, P5, P6, P8, P14</td>
</tr>
<tr>
<td>26-30</td>
<td>4</td>
<td>P1, P7, P11, P15</td>
</tr>
<tr>
<td>31-35</td>
<td>3</td>
<td>P3, P10, P13</td>
</tr>
</tbody>
</table>

The students can be divided into four groups quite uniformly. Five of the students have most descriptions and their descriptions concern mainly on the assessment and the change.

For further analysis the 399 descriptions were grouped into eight code families, which were then named as education, evaluation, self-assessment, instruction, background, science-technology-society, sciences and environment (Table 9, with the code frequencies in each family).
### Table 9. Code families

<table>
<thead>
<tr>
<th>code family</th>
<th>codes</th>
<th>quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>education: mainly neutral comments what has happened</td>
<td>course at the beginning, biology, physics, chemistry, science and technology entity, technology and society course, geography, teaching project, newspaper project</td>
<td>91</td>
</tr>
<tr>
<td>evaluation/critics: mainly critical comments on the education, benefits of the education for the teacher profession</td>
<td>evaluation, benefits</td>
<td>86</td>
</tr>
<tr>
<td>self-assessment: mainly comments on own learning and change in the thinking</td>
<td>change, reflection</td>
<td>77</td>
</tr>
<tr>
<td>instruction: mainly comments on the ways of science teaching and their own learning</td>
<td>teaching, learning, learning styles</td>
<td>49</td>
</tr>
<tr>
<td>background: comments on earlier studies, what students have expected from the education, what they think will happen in the future work and why they have chosen this education</td>
<td>background, waiting, hopes, future, choice</td>
<td>45</td>
</tr>
<tr>
<td>science-technology-society: comments on the relationships between science, technology and society</td>
<td>technology relation, society, environment</td>
<td>31</td>
</tr>
<tr>
<td>science: mainly mentions concerning the nature of science or scientific knowledge</td>
<td>science and scientific knowledge</td>
<td>20</td>
</tr>
<tr>
<td>environment: attitudes to nature</td>
<td>environment</td>
<td>12</td>
</tr>
</tbody>
</table>

Mostly the students commented on the education, as what happened and when. Secondly, they evaluated the education. They criticized the courses separately and also the activities during the education. And thirdly, students told about their own learning process and about changes in their thoughts or action. Code families and the quantities of the descriptions of each student in these families are shown in the Table 10.
Table 10. Students’ descriptions in codes families

<table>
<thead>
<tr>
<th>code family</th>
<th>students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 Totals</td>
</tr>
<tr>
<td>education</td>
<td>11 11 3 6 8 5 3 6 4 7 2 0 9 7 8 1 91</td>
</tr>
<tr>
<td>evaluation</td>
<td>9 7 4 8 6 2 8 3 6 7 4 0 7 8 5 2 86</td>
</tr>
<tr>
<td>self-assessment</td>
<td>2 2 12 0 3 8 6 4 2 5 1 6 9 3 8 6 77</td>
</tr>
<tr>
<td>instruction</td>
<td>2 1 7 1 3 0 5 1 3 6 6 4 4 2 2 2 49</td>
</tr>
<tr>
<td>background</td>
<td>5 0 4 4 3 4 3 4 3 3 3 3 2 3 1 0 45</td>
</tr>
<tr>
<td>srs</td>
<td>1 0 2 0 0 4 0 3 0 1 4 4 4 2 4 2 31</td>
</tr>
<tr>
<td>sciences</td>
<td>0 0 3 1 0 0 1 0 0 3 6 3 0 0 0 3 20</td>
</tr>
<tr>
<td>environment</td>
<td>0 0 2 0 0 1 0 0 0 0 1 4 2 0 1 1 12</td>
</tr>
<tr>
<td>Totals</td>
<td>30 21 35 20 23 26 21 16 32 28 20 35 25 28 16 399</td>
</tr>
</tbody>
</table>

According to the quantity of the descriptions of each individual student, the students are categorized. Two largest code families of each student were searched from the Table 10. For example student 1 had most descriptions in the families of education and evaluation, student 7 in the families of evaluation and self-assessment and student 11 in the families of instruction and sciences. According to the two most active code families the students could be grouped as follows (Table 11).

Table 11. Students grouped according to the two most active code families

<table>
<thead>
<tr>
<th>code family</th>
<th>students</th>
</tr>
</thead>
<tbody>
<tr>
<td>education</td>
<td>P1, P2, P4, P5, P8, P9, P10, P13, P14, P15</td>
</tr>
<tr>
<td>evaluation</td>
<td>P1, P2, P4, P5, P7, P9, P10, P13, P14</td>
</tr>
<tr>
<td>self-assessment</td>
<td>P3, P6, P7, P8, P12, P13, P15, P16</td>
</tr>
<tr>
<td>instruction</td>
<td>P5, P11, P12</td>
</tr>
<tr>
<td>background</td>
<td>P8</td>
</tr>
<tr>
<td>science-technology-society</td>
<td>P12</td>
</tr>
<tr>
<td>science</td>
<td>P11, P16</td>
</tr>
<tr>
<td>environment</td>
<td>P12, P3, P13</td>
</tr>
</tbody>
</table>

Most of the students described education in some way. The background had a remarkable role in one of the narratives, namely, in that of student P8. Science-Technology-Society was described mainly only by one student. The above mentioned Table 11 has still been investigated more carefully to find some combinations of code families, which
could still condense the image about students’ thoughts without losing essential information. Finally, it was found that it is reasonable to group students into three groups, which are now shown in Table 12. Now each student belongs to one group formed from the code families, and the amount of students’ descriptions. Each group is described with some typical descriptions.

Table 12. Student groups

<table>
<thead>
<tr>
<th>group mostly</th>
<th>students belonging to the group</th>
<th>example</th>
</tr>
</thead>
<tbody>
<tr>
<td>...reflects their own action and</td>
<td>P3, P6, P12, P13, P15, P16</td>
<td>“I don’t think anymore, that I should have everything in my head, rather I am able to find the information when needed.&quot; P3</td>
</tr>
<tr>
<td>tells about change in their thinking or</td>
<td>P1</td>
<td>“For me sciences have provided multifaceted and meaningful learning experiences; hopefully I can use, what I have learned, with my future pupils.” P11</td>
</tr>
<tr>
<td>action concerning science, evaluate their</td>
<td></td>
<td></td>
</tr>
<tr>
<td>learning.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...reflects and on the other hand tells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>about sciences much more than others.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...evaluate the education without</td>
<td>P4, P7, P9, P10, P14</td>
<td>“This kind of entity benefits teaching of several subjects at schools.&quot; P10</td>
</tr>
<tr>
<td>evaluating their own action or tells about</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the benefits of the education, no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reflection on their own action.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...comments neutrally the education,</td>
<td>P1, P2, P5, P8</td>
<td>“Chemistry was interesting but for me it was also necessary to study more upper secondary school books.” P2</td>
</tr>
<tr>
<td>documentation without reflection.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The narratives showed that students had three different ways to write about the education. One group called here “reflectors” (7 students) reflected their own actions and learning and told also about the changes in their thinking about science or in action in everyday life. The second group called here “evaluators” (5 students) evaluated the education without evaluating their own actions or without telling about practical benefits of the education. The third group called here “commentators” (4 students) commented or documented neutrally the education without any reflection.
“Reflector” - Me as a science learner

Student P3 wrote in the narrative “Me as a science learner” about her/his interests in nature ever since s/he has been a child and about her/his primary school time

…ever since primary school geography and biology and to some extent also chemistry have belonged to my favourite disciplines. P3

S/he liked less physics which is typical for the primary school teacher students as Ahtee and Rikkinen (1995) have noticed in their study of Finnish primary school teacher students. This student told that s/he has got a lot from science studies and pointed out the connection between science and nature.

It has been a pleasure to notice that when I have learned a new thing it can immediately be found in the nature. P3

Nature and physics are often seen as separate things. When students like nature, it normally follows, that they like biology as well. Biology and nature are mostly seen as the same thing. This reflecting student acknowledged the understanding of the phenomena and of the causal relations which are essential features in science.

It has been interesting to understand things and reasons behind the events. P3

S/he saw the understanding of causal relations being rewarding and connected it many times to the nature.

This “reflector” told about science knowledge during her/his school time.

…in the comprehensive school things became familiar as separate and own entities. In the comprehensive school the connections between science disciplines were absent. Only when I was in the upper secondary school I started to understand that sciences are a big and uniform entity, which has been divided because of the necessity to different disciplines. This image has been further reinforced in my vocational studies, in which during the teaching the connections between things have been pointed out. Also in my minor studies I have been able to broaden my science view. P3

S/he has learned that science is not only about facts which must be remembered and this is partly due to Science and Technology Education. S/he told about her/his vocational studies referring to university studies. Her/his view about teacher education was typical for many students. They
are studying to be primary school teachers and they like to get practical hints directly for the future teaching work instead of understanding the purpose of the education to get the ability to acquire knowledge. This view of the education is very challenging for the educators.

The student also wrote of her/his way to study:

*My study style is very traditional...I like to get as big a knowledge capital as possible for myself. I have, however, perceived in studying science disciplines that I can not and I am not able to embrace all the knowledge.* P3

The student has changed her/his mind about science learning. S/he has noticed "how important it is to know how to acquire knowledge". S/he pointed out observation and the understanding of the "big lines" but acknowledged as a big capital the broad basic knowledge about nature and science things. Besides science nature was highlighted in her/his text the whole time. S/he also told about the Science, Technology and Society course and how s/he during this course learned to connect different things and the technology to science. Her/his view about science as a part of nature has widened. S/he thought that s/he is more ready for teaching. Finally s/he still highlighted her/his view of learning.

*I don’t believe that the teacher can pour knowledge into my head but I am an active searcher of knowledge. ..teachers have given me directions and impulses...* P3

As a reflector s/he told about her/his view of science, science learning and teaching, as also of Science and Technology Education. S/he told about her/his own viewpoint of education and reflected her/his own changes.

"Evaluator" – Science studying in the academic year 1999-2000

Student P7 represents another group – evaluators. S/he started telling how s/he heard about Science and Technology Education. S/he told that s/he got interested immediately because also for her/him sciences have been favourite disciplines since primary school. The minor subject information seems to be meaningful to encourage students to Science and Technology Education. The student was very satisfied with the studies which have been “variation besides educational studies”. Variation was due to the courses which have been arranged in the lecture rooms of other faculties.

*It was possible to be with in the atmosphere of science studying.* P7
The things under consideration have been interesting and s/he “got new knowledge to join to her/his own knowledge”. The level of the education was suitable, teachers were well aware about things under consideration and were able to tell about them in an interesting way. All the knowledge was useful and meaningful for the teacher profession and other life.

In the science teaching s/he acknowledged the trying by yourself, testing, and observing. S/he has grown up to teach science and told about science studying.

_During the spring I gradually developed the feeling that I myself could arrange science teaching in the ways in question. To my opinion it is essential in science studying that one is able to connect knowledge and to do own conclusions._ P7

After Science and Technology Education s/he was satisfied with her/his achievements, with the knowledge and materials circulated in the courses and inspiration to teach science at school. S/he told about the education and her/his own motivation, but did not express clearly the changes in her/his thoughts or behaviour. S/he evaluated the courses and wrote about her/his view of science learning, but looked it more from the viewpoint of the courses than from the one of her/his own. Compared to the “reflector” the expressions were more neutral.

“Commentator” – End reflection

The commenting student P1 saw the Science and Technology Education interesting. According to her/him scientific disciplines and theories were considered multifaceted during the education. Newspaper project was nice. Chemistry and biology have been her/his strong disciplines at school, thus s/he expected interesting moments. S/he liked more chemistry course than biology course. Physics nearly caused grey hairs, but fortunately there were no calculations. Teaching handouts were good and made the studying easier. Teaching project was also nice. S/he commented geography course.

_Geography course was a real pearl._ P1

This course was so interesting that the student started to study geography at the Department of Geography. S/he commented also the Science-Technology-Society course.

_..was really a massive package. Lectures gave justified knowledge about society. Technology practises emphasized, to my opinion, too much one thing._ P1
Perlos' project was also good but left an uneven view of the project. S/he hoped that the education should respond more to school science. If the teaching entity was so that it would respond more environment and science studies at school. PI

This student commented every course and part of the education. S/he did not evaluate her/his own learning or thoughts but assessed the teaching of the courses. Mainly her/his view of education was positive but however s/he could not see any changes in herself/himself in the narrative.

Finding of different types of students is not surprising and agrees also with the research findings reported by Bolton-Lewis et al. (2001) which show that there are many-sided relations between the conceptions of teaching and approaches to learning. Students at the same university class do not necessarily experience the same worlds. For example, a student with limited prior knowledge and a superficial approach in a class which is designed to facilitate a deep approach will see the situation quite differently from a student who has the requisite knowledge and adopts a deep approach. Although research reports concern teaching and learning, students' position to education studied in this inquiry has the same features. The reflecting students consider education more deeply than the evaluating and commenting students can do. The commenting students have the most superficial approach to education. In summary, students described science in different ways. Three types of students were found.

5.5 Students' views of science

Things which the students highlighted in their narratives ranged from their own background to the learning results, from the self-reflection to the assessment of the courses, and from the changes in their thoughts to learning facts. Although every code is interesting in this study, however, science and instruction code families have appeared to be the most essential topics in the context of Science and Technology Education, and they were chosen to the further analysis. In the educational literature students', teachers', and pupils' views and conceptions of science have been investigated since 60's (see Duit 2004).
5.5.1 How do the students describe science?

One of the primary school teacher students wrote a lot of sciences in her/his life.

I have got a lot for myself in studying scientific subjects, because the whole time they have been present in my life. It has been a great joy to notice that when I have learned a new thing I have immediately found after the learning the same in the nature. It has also been interesting to understand things and the reasons behind the events. Often things are taken as self-evident truth without thinking about the factors on the background. It has been rewarding to be able to explain and become aware of the causes which have caused a special thing and of everything else which we can not see and how it is related to, for example, some weather phenomena. P3

This student found the science important for her/him and sciences have always been in her/his life. S/he respects the understanding of the causal relations and the connections between the studies and the real world. S/he continued telling about sciences.

When I was in the comprehensive school, things in sciences became familiar as separate and own entities. The relations between science subjects were missing at the comprehensive school. Only when I was in the upper secondary school I started to understand sciences as being a big and uniform whole, which has been divided because of the necessity to different subjects. Then I started to think scientific subjects as supporting topics to each other. This conception has been further reinforced in my vocational studies, in which the relations of the things have been pointed out. Also in my minor studies I have been able to widen further my scientific view. P3

Already at upper secondary school s/he understood the nature of science as a whole, not a collection of facts. But s/he did not express the differences between scientific subjects. The education has reinforced her/his view of science but not changed it.

Also another student thought that science is an entity.

Only during the last years I have learned to understand biology, geography, physics and chemistry as being a part of a larger whole-science. P12

This student also connected science to everyday life.
I have learned to see science as a part of everyday life and to observe nature phenomena outside the study book from the own environment. P12

Another student believed that...

...sciences are one of the subject entities closest to the real life at school, thus, it is possible to make them very interesting and concrete, if one has courage to put the book aside. P10

S/he wrote also.

In general, I felt, that I got a new viewpoint to sciences. I think more investigatively and certainly I have courage after this, at least to try, to illustrate things for pupils by taking examples from the real nature and to teach pupils phenomena many sided also with experiments and with an investigative grip. P10

The student thought that her/his view of science has changed remarkable, during the education. Mostly s/he connected her/his ideas to the teaching of sciences and saw sciences as subjects in which investigations should be done.

The third student thought.

To me sciences have given many-sided and meaningful learning experiences, I hope that I can use that with my future pupils. P11

S/he wrote also.

Since the primary school biology has interested me, from all the subjects belonging to sciences... mostly. P11

Although biology is quite an exact subject, all scientific subjects are exact, it was interesting to study it because of its closeness to human beings. P11

Sciences are many-sided, there is always something new to learn. P11

The nature is a huge, wide and wonderful whole, which the human being can never fully rule-and it is not even necessary. The same concerns science, too. P11

Although this student thought that sciences are exact, s/he was also of that opinion that not all of the sciences can be known. This student saw sciences mostly as biology or as nature studies.

Scientific knowledge has also had the same properties in the students’ descriptions as can be seen below in the descriptions about the unknown parts of science.
In studying scientific subjects I have understood that I am not able to take in all knowledge, I have noticed how important it is to learn to search knowledge. In my opinion it is important to observe and understand large lines in science. When one has learned and understood some basics, it is easy to increase knowledge from different sources. I do not think anymore that everything should be in my head, but I am able to search and to get hold of the necessary knowledge when ever needed. P3 Not every question has an immediate answer, some question can never be answered. P16

But there were also other views.

A lot of different things and sometimes even very small details have to be remembered. P4

Knowledge also changes continuously. P16

Often students told about science in connection with science learning or teaching.

In my opinion it is a good thing that in science courses, things are dealt with by trial, by testing or by observing. One learns in the same way about things connected to science outside studies in everyday life. P7

They also connected science to the everyday life.

Nowadays one looks at everyday phenomena more exactly and deeper – many times I find myself thinking what there is behind the phenomenon. Things are considered also in a more critical way: everything is not necessarily how it first appears. P16

The students described their thoughts on science in many ways in the narratives. Some students thought that science is about facts, some other students that it is an entity to be understood. For some students science is connected tightly to everyday phenomenon and some students look it from the viewpoint of science teaching. The students had chosen different viewpoint to consider science or scientific knowledge in their narratives. The third research question in this part of the study “How do the students describe science?” has now been answered.

5.5.2 What are the students’ views of science like?

In this study the interest has been to find out more widely about students views of science in a special context and by using the narrative method. The mainstream of the research of the views of science and
more often of the nature of science has been carried out by using tested questionnaires including statements. Conceptions of the nature of science have most often been studied by using questionnaires with statements such as: “What is science?”; “What is scientific knowledge?”; “Where do scientists get their ideas from?” and so on. Standardized instruments used to assess Nature of Science views are, for example, Test on Understanding Science (TOUS), Nature of Science Scale (NOSS), Views of Science Test (VOST) and so on (see the review of Abd-El-Khalick 2000 and later Khishfe and Abd-El-Khalick 2002). Quantitative methods are used together with these questionnaires. During the past ten years, interviews and other qualitative methodologies have been more widely used to assess students’ knowledge about the nature of science. Both quantitative and qualitative ways to consider teachers’ conceptions of the nature of science have been used for example by Mellado (1997). The conceptions about the nature of science by using writings which were answers to questions about students’ thoughts on science and scientific knowledge have been studied by Stein and McRobbie (1997). The knowledge of science involves laws, models, theories, concepts, ideas, experimental techniques and procedures of science. The knowledge about how scientists decide which questions to investigate, how scientists interpret data they have collected, how scientists decide whether or not to believe in the findings published in research journals refers, according to Ryder et al. (1997, 1999), to the nature of science. During the process of this study an article by Rubin and Cohen (2003) was published, in which they asked students to name and recognize scientists, to reason their choice and draw a scientist to find the images of science among pre-service teachers. Also the questionnaires are being developed towards more qualitative assessment (Lederman et al. 2002).

Students’ answers have been categorized into six groups according to the essential meaning of science which students pointed out in the study of Stein and McRobbie (1997). On the basis there were the following ideas: that scientists are themselves an integral part of the world they are studying; even though scientific progress occurs over time, it does so within the context of history and specific situation; and therefore scientific knowledge and understanding are both tentative and inconclusive on a macro level; scientific knowledge is not an objective and definable truth, but human creativity and imagination that pushes scientific knowledge along, into the direction in which it
moves by being determined by the context. Categories in their study are as follows: science is what is done or learnt at school; science is seen as a consumable product; science is a study of the world; science is a process; science is seen as dynamic knowledge; and science is seen as influenced by the social context.

Students' talk about the nature of scientific knowledge has been also classified into nine interpretive repertoires: intuitive, religious, rational, empiricist, historical, perceptual, representational, authoritative, and cultural (Roth and Lucas 1997). Also, the term contemporary (i.e. postpositivist) view of scientific theory, knowledge, and the role of a scientist has been used (Palmquist and Finley 1997). Within this view the progression of scientific knowledge is not continuous; scientific knowledge is tentative; it is created and validated by common acceptance within the scientific community; scientists create knowledge based on prior knowledge, observation, and logic; the tentativeness of knowledge is related to how much people work on it; and the truth is defined as an accurate description of nature. On the other hand there is the traditional (i.e. empiricists or positivist) view of scientific method. Within this view scientific knowledge corresponds directly to reality, scientific knowledge increases by accretion from observations, scientific knowledge progresses by an accumulation of observations, scientific knowledge is proven or disproven owing to the direct influence of observations, scientific knowledge is unchanging, scientific data must not be interpreted by the scientist. Students also can have a mixed view of scientific method (Palmquist and Finley 1997, Haidar 1999). Contemporary view can be named also as a constructivist view (Haidar 1999).

Definitions for both the nature of scientific knowledge and science presented in the literature during the past 30 years are multifaceted. The latest consensus view of the nature of science has been found in eight international science standard documents (McComas et al. 1998). Philosophers, historians, and sociologists disagree on a specific definition for the nature of science. However, within a certain period of time and at a certain level of generality, there is a shared wisdom, even though no complete agreement, about the nature of science. For example scientific knowledge while durable, has a tentative character; science is an attempt to explain natural phenomena; and science is a part of social and cultural traditions (see i.e. McComas et al. 1998). Also curiosity, dynamic, aims at comprehensiveness and simplification,
many methods and openness are connected to the nature of science. Characterizations remain fairly general, and philosophers of science, historians of science, sociologists of science, and science educators are quick to disagree on a specific definition for the nature of science (Akerson et al. 2000). Similar to scientific knowledge, conceptions of nature of science are tentative and dynamic. Throughout this study I use the phrase ‘the nature of science’ instead “nature of science”, or NOS, or NoS to reflect the lack of my belief in the existence of a singular “NOS”. I have chosen “the nature of science” purely from the viewpoint of linguistics and despite the definite article it refers to an unspecific definition. The reader must also be reminded that the view of the nature of science is not in focus in this research. Rather I am interested in the view of science to denote not only aspects of the nature of science but also the social influences on science and technology, the nature of causal links, risk and risk assessment, and the impact of science and technology on society. The term “nature of science” is used in the literature to refer to a narrower group of philosophical and epistemic issues about the nature of scientific knowledge. The term “view of science” is seen here as more comprehensive and it embraces a wider range of issues found in the themes of the narratives. Conceptions of the nature of science have changed throughout the development of science and systemic thinking about its nature and working.

The general views of the nature of science and scientific knowledge presented in the literature, the view of science as a process to generate and test knowledge, and the developmental and testable nature of scientific knowledge, are views relevant to the population of pre-service elementary teachers too (Meichtry 1999). The students’ statements grounded on the phrases the students used in their responses can be categorized as Ryder et al. (1999) have done. Their questions concerned scientific methods, inquiry and social dimension of the inquiry. Another method to study primary student teachers’ conceptions of the nature of science, the newspaper science reports, is used by Murcia and Schibeci (1999). Modern view in their work refers to contemporary or constructivist views discussed above. Five categories have been used to clarify the students’ responses to the question “What is science?”. study of the world, process, body of knowledge, search for new developments and no response.

At the beginning of the 21st century students’ knowledge about the nature of science in the framework of distal and procedural knowledge
has been considered by Hogan (2000). Distal knowledge of the nature of science is students' declarative knowledge about professional science, including the nature of scientific knowledge and scientist' epistemological commitments. Proximal knowledge of the nature of science is students' personal understandings, beliefs, and commitments regarding their own science learning and the scientific knowledge they produce and encounter. Distal knowledge corresponds the knowledge concerning science in the preceding chapter. Recently views of the nature of science have been studied also by Khishfe and Abd-El-Khalick (2002). They have investigated the influence of an explicit and reflective inquiry-oriented instructional approach compared to an implicit inquiry-oriented instructional approach on sixth graders' understandings of the nature of science. The study emphasizes four aspects of the nature of science: tentative, empirical, imaginative and creative. The views of pupils have been categorized either to be naïve (i.e. scientific knowledge is certain or true and does not change) or informed (i.e. scientists are not certain about the way dinosaurs look like because they use their imagination to get an understanding of the picture of a dinosaur).

Also science teachers' beliefs of science as also their beliefs of teaching and learning respectively have been investigated by Tsai (2002) simultaneously with Khishfe and Abd-El-Khalick. He categorized the descriptors found from the interviews into three categories as follows: traditional, process, and constructivist. The traditional category perceives scientific knowledge as correct answers or established truths. The process category perceives scientific knowledge as facts being discovered through the scientific method or by following codified procedures. The constructivist category views science as a way of knowing. The traditional category is supported by empiricism and logical positivism; the process category is supported by naïve realism, while constructivism category is supported by a broadly constructivist philosophy (Tsai 2002). Students' views of the nature of science in the context of stories and peer collaboration have been studied by Tao (2003). In his study many students possessed entrenched inadequate views of the nature of science.

The categorization of views of science to contemporary, traditional and mixed views by Palmquist and Finley (1997), and respective categories found by Haidar (1999), Murcia and Schibeci (1999), Khishfe and Abd-El-Khalick (2002) and finally by Tsai (2002) were
on the background in the categorization of the descriptions found in this study. The reader must be reminded again, that in this study the views of science are under consideration instead of the views of the nature of science. The outcome of the data analysis in this study is, however, the discovery of the four categories describing four different ways to consider science and scientific knowledge. The way to consider science has guided the categorization of the students’ thoughts. The view categories in this study are contemporary, practical, pedagogical and traditional (Table 13). The categories are illustrated by a brief description in Table 13 from the students’ written statements. The students have seen the science as a wide branch of knowledge (5 descriptions) and science knowledge is not absolute (3) (contemporary view), science is near everyday life (5) (practical view), science is making inquiry (4) (pedagogical view) and science is about facts (2) (traditional view).

<table>
<thead>
<tr>
<th>view</th>
<th>description</th>
<th>quantity</th>
<th>student</th>
</tr>
</thead>
<tbody>
<tr>
<td>contemporary</td>
<td>...science knowledge is not absolute...</td>
<td>8</td>
<td>P16r(3)</td>
</tr>
<tr>
<td></td>
<td>...science is a wide branch of knowledge...</td>
<td></td>
<td>P3r(2), P11r(2), P12r</td>
</tr>
<tr>
<td>practical view</td>
<td>...science is near everyday life...</td>
<td>5</td>
<td>P3r, P7c, P10s, P12s, P16r</td>
</tr>
<tr>
<td>pedagogical view</td>
<td>...science is making inquiry...</td>
<td>4</td>
<td>P7c, P10s (2), P12s</td>
</tr>
<tr>
<td>traditional view</td>
<td>...science is about facts...</td>
<td>2</td>
<td>P14s, P11r</td>
</tr>
</tbody>
</table>

Table 13. Students’ views of science found from the narratives (r refers to reflecting, e to evaluating and c to commenting student)

Four students had a contemporary view of science, five students saw science (physics) as a practical subject, four students thought at first science (physics) as a teaching subject and two had a traditional view of it. I must remind the reader that the aim in this study was to find out what the students highlighted and thus the students used the freedom to highlight the subjects from different viewpoints. I believe, however, that their choice depends on their view of science.

Primary school teacher students did not separate sciences from each other when they described them. When telling about the education
they, however, described different courses separately, thus also biology, chemistry, geography and physics. These descriptions about a subject matter were also categorized with the aid of the key phrase in order to find deeper understanding and are shown in Table 14 with the respective frequencies.

Table 14. Descriptions concerning different science subjects

<table>
<thead>
<tr>
<th>category of descriptions</th>
<th>biology</th>
<th>chemistry</th>
<th>geography</th>
<th>physics</th>
<th>total</th>
<th>students</th>
</tr>
</thead>
<tbody>
<tr>
<td>basics of subject</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>15</td>
<td>P1c, P2c, P4c, P6r, P7e, P8c, P9e, P10e, P13r, P14c, P15r</td>
</tr>
<tr>
<td>school instruction</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>P2c, P5c, P6r, P7e, P8c, P10e, P13r, P14c</td>
</tr>
<tr>
<td>interest</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>7</td>
<td>P1c, P2c, P7c, P10e, P14e</td>
</tr>
<tr>
<td>difficulty</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>6</td>
<td>P1c, P2c, P4c, P5c, P15r</td>
</tr>
<tr>
<td>exercises</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>P1c, P4c, P11r, P13r</td>
</tr>
<tr>
<td>everyday life</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>4</td>
<td>P1c, P4c, P13r</td>
</tr>
<tr>
<td>environmental attitude</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>P13r, P15r</td>
</tr>
</tbody>
</table>

Physics was most often connected to school instruction and it was also connected to the everyday life. It was also regarded clearly as the most difficult subject. Chemistry was also seen as a school subject and accompanied by exercises. As seen in the previous chapter, biology was less commented. The students told that the biology course has given the basics of the subjects. Geography instead was seen as the most interesting subject or course, which also produced the basic content knowledge. Environmental attitudes were connected mostly to geography and not at all to physics or chemistry. When considering separate subject courses, they were seen as “giving” basics of the subject which refers to a traditional view of science as facts. Secondly, the subjects were seen through the viewpoint of school referring to the pedagogical view. Thirdly, students described their interest and then the difficulty of subjects. Students mentioned less everyday life
which refers to the practical view in the aforementioned categories. Interest, difficulty and environmental attitude descriptions do not refer clearly to the aforementioned categories; exercises refer both to the pedagogical view and the contemporary view. It is found out that primary school teacher students’ view is often contemporary when considering science. However, when they considered different science subjects the view was more traditional or pedagogical.

The descriptions about physics shown in the preceding Table are clarified in Table 15, as also the key phrases and the students respectively.

### Table 15. Students’ views of physics found in the narratives

<table>
<thead>
<tr>
<th>category of descriptions</th>
<th>description</th>
<th>quantity</th>
<th>students</th>
</tr>
</thead>
<tbody>
<tr>
<td>school instruction</td>
<td>...concrete instruction hints...suitable base for school instruction...I can now bring forward my knowledge for the pupils...</td>
<td>6</td>
<td>P2c, P5c, P6r, P10c, P13r, P14e</td>
</tr>
<tr>
<td>difficulty</td>
<td>...near to get grey hair...high-flown...most difficult...</td>
<td>5</td>
<td>P1c, P2c, P4e, P5c, P15r</td>
</tr>
<tr>
<td>conversations</td>
<td>...more conversations...things, which you not normally think about...everyday viewpoint...</td>
<td>3</td>
<td>P1c, P4c, P13r</td>
</tr>
<tr>
<td>and everyday life</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>basics of objects</td>
<td>...revised...basic...brought up to date...</td>
<td>3</td>
<td>P9c, P10c, P14e</td>
</tr>
</tbody>
</table>

Primary school teacher students said mainly that the physics course has given concrete help for the future profession. They also found physics difficult. The connections to everyday life were also pointed out. The physics course was seen to produce basic knowledge about the subject either new or revised old knowledge. The descriptions by the seven students about physics belong to two or three different categories. Five students did not describe physics at all. “Basics of objects” category in this study seems to respond to the first approach with formulae in the study reported by Bolton-Lewis et al. (2001) although in our education formulas are not used. In their study secondary school teachers had three different approaches to physics. In addition to the group of teachers understanding physics as being a set of formulae and related calculations, a second group saw physics as a practise revolving
around a set of theories that provide an explanatory system and the
final group conceptualised physics as a way of understanding the
natural world. “Everyday life” category responds to the second group
and “school instruction” category descriptions have similarities with
the final group. Students who had contemporary view of science did
not describe physics at all. One student who had both practical and
pedagogical view of science saw physics through school instruction
and basic knowledge. One of the students with a traditional view of
science found physics difficult. Other students who described science
in some way did not describe physics course or subject.

5.5.3 Concluding remarks on the students’ views of
science

The students’ understanding of the nature of learning strategies that
they consequently employ evolve throughout their time at school. The
way the nature of knowledge is presented over the years of schooling is
likely to affect students’ understanding of it, and, consequently, how
they relate to knowledge. If science is presented to students as a body
of knowledge, proven facts, and absolute truths, then they will focus
on memorizing facts and think that all knowledge can be ascertained
through specific proof procedures embedded in the scientific method.
If, on the other hand, students experience science as a continuous
process of concept development, an interpretive effort to determine
the meaning of data, and a process of negotiating these meanings
among individuals, then students might focus on concepts and their
variations. (Roth and Roychoudhury 1994.)

It can be concluded, in this study, that according to science
descriptions the students have four different ways to see science:
contemporary, pedagogical, practical and traditional. However, when
we look at the descriptions about individual subject courses of the
education it is seen that the views of the students are more complicated.
Seven of them have expressed some aspects of contemporary view in
some of the contexts considered above. Eight students have expressed
some aspects of practical view. And twelve of the students have
expressed some aspects of pedagogical view as also of traditional view.
I call these views “wholly” and “partly” contemporary, pedagogical,
practical and traditional views referring to the science descriptions and
subject descriptions, respectively (Table 16).
Table 16. Students’ views of science found in the narratives

<table>
<thead>
<tr>
<th>view</th>
<th>wholly – from science descriptions</th>
<th>partly – complemented from subject descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>contemporary</td>
<td>P3, P11, P12, P16</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1, P4, P13</td>
</tr>
<tr>
<td>pedagogical</td>
<td>P7, P10, P12</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1, P2, P4, P5, P6, P7, P8, P10, P11, P13, P14</td>
</tr>
<tr>
<td>practical</td>
<td>P3, P7, P10, P12, P16</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1, P4, P13</td>
</tr>
<tr>
<td>traditional</td>
<td>P4, P11</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P1, P2, P6, P7, P8, P9, P10, P13, P14, P15</td>
</tr>
</tbody>
</table>

There is a generalized agreement in the conclusions drawn from the investigations, conducted during the past 40 years, that students have an inadequate understanding of the nature of science. In this study it was reasonable to form categories in a different way from that in the literature. Besides the contemporary and traditional view of science primary school teacher students had also pedagogical and practical views of science. However the students’ views did not represent purely any of the categories, but were mixtures of two or more views. It has also to be noticed that the primary school teacher students in this study had no coherent view of science in all its aspects. They may have contemporary view when they speak about science, which they do not express at all in the context of separate subjects. Students may have a traditional view of scientific knowledge and express contemporary view in some aspect in the context of subjects. For example students P1 and P13 have expressed every view in some context. The multidimensional situation is shown in Figure 6.
Figure 6. The multidimensional views of science of individual students

The reader must be reminded, however, that the descriptions of different subjects are strongly interpreted to coincide the different views. Science descriptions represent, however, more clearly the categories of the views than subject descriptions do. This finding is in agreement with the findings of Roth and Roychoudhury (1994). In their study younger physics students held views that were not all concurrently commensurable with the same epistemological position. A student who claimed that scientific knowledge approximates truth and exists independently of human conceptualization could also maintain that scientific knowledge is a function of the scientists' social environment, as well as maintain a preference for studying science in a self-directed inquiry laboratory where contradictory interpretations are negotiated. The results in this study about complicated views agree also with the study where teachers held traditional, constructivist or mixed views of these two views depending on the item carried out by Haidar (1999). Pre-service primary science teachers did not have
a conception of scientific knowledge which was coherent in all its aspects also in the study of Mellado (1997). Rather than a single conception for each teacher, he refers to dominant tendencies or orientations. They all had a deeply ingrained set of clichéd ideas on the empiricist scientific method. The results of this study are thus parallel to Mellado’s conclusions. Another method to study primary student teachers’ conceptions of the nature of science, the newspaper science reports, has been used by Murcia and Schibeci (1999). They also noticed that student teachers articulated elements which were not in accordance with modern views of the nature of science.

In the study about science undergraduates it has been found that the majority of students have made statements that knowledge claims could be proven to be absolutely right (Ryder et al. 1997). University students tend to advance towards a Popperian view in which scientific ideas are either accepted or falsified on the basis of empirical data. This contrasts with a Kuhnian view in which social processes, in addition to empirical processes, are considered influential in the progress of science. In this study primary school teacher students had both views to some extent. Also 15-year-old students are using a mixture of school knowledge, which depends upon what their science teacher has discussed with them, and everyday knowledge that emanates from school as Solomon et al. (1994b) have noticed. Which category of knowledge is used depends upon the question asked. In this study it depended on the subject described. Life-world knowledge is a social construction like local culture which provides ample opportunities for personal choice (Solomon et al. 1996). Its cafeteria character allows students to use their own cognitive preferences in selecting what may seem to be the “right” answer to a question on which they have had no formal guidance.

Irrespective of the assessment instruments used, studies have repeatedly indicated that elementary and secondary science teachers’ views were not consistent with contemporary conceptions of the nature of science (Akerson et al. 2000). In this study, for example, student P4 showed traditional view of science, science being facts, but, however, contemporary view in some subpart of science. The reason why the students express more contemporary view of science than of its subparts may be due to the course arrangements. The beginning and the final course – ‘Science and Technology as a Knowledge and Action’
and ‘Science, Technology and Society’ – discuss science education in general. In these contexts the nature of science and the contemporary pedagogical methods are discussed. During the subject courses students study content knowledge and they do not accumulate the knowledge of the other courses in these subject courses or vice versa. In this sense they have very faceted knowledge, the view depends on the context under consideration. The answer to the fourth research question in this part of the study “What are their views of science like?” has been found.

5.6 Students’ views of science instruction

During the past 40 years the research in science education has been focused mainly on the views of science. From these quantitative investigations research has moved towards qualitative research and at the same time the interest has been aimed towards the views of the nature of science teaching and learning. Since 2000, more interest has been focused on the beliefs and views of teaching and learning science. Some researchers have studied both the views of the nature of science as also the views of science teaching and learning.

5.6.1 How do the students describe science instruction?

The code family instruction included the codes teaching, learning and learning style. Students described much more science instruction than science itself. They wrote about teaching.

_I don’t believe that the teacher can pour learning into my head but I am myself an active searcher of knowledge and its processor. When I have studied science, teachers have given me directions and hints, which I have started to investigate._ P3

_I am more ready to widen my teaching._ P3

On the other hand the content knowledge was seen as an important skill for a teacher.

_…a teacher needs indeed subject knowledge at school_… P4

_The one who teaches science must have her/his background knowledge in order._ P5
The primary school teacher students also pointed out the different science teaching methods, trying, testing, and observing.

"In my opinion it is a good thing, that in science courses things are dealt with by trial, by testing by observing. In the same way one learns about things connected to science outside studies in everyday life." P7

This student continued.

"In my opinion it is essential in science studies that one can connect knowledge and make own conclusions about things. These things will be demanded also from a science teacher." P7

Besides making conclusions also illustration and investigations were mentioned and preparation was pointed out.

"I have courage to try to illustrate things for pupils by taking into account examples from the real nature and teach pupils phenomena many-sided also on experiments and in an investigatory way." P10

"Of course science lessons, in order to be successful, require a lot of preparatory work from the teacher, but many times it is rewarding, when one notices pupils’ enthusiasm and how they get ideas." P10

Also environmental education aspect was pointed out.

"I believe that by going in the nature the senses become more sensitive to see, hear, taste, smell and feel." P12

"A science student as also a science teacher must accept that the enjoyment connected to the nature and the responsibility go together hand in hand." P12

And action was also mentioned in the sense of pupils’ action.

"Besides the development of pupils’ knowledge and feelings in my teaching I would like to point out their own action in science." P13

The teachers’ role was described.

"The teacher does not have to be a beserwisser and infallible, but first of all she has to be interested in the subjects, which she teaches." P16

The students commented learning through their own learning.

"It has been a pleasure to notice that after learning a thing one can immediately see the same thing in the nature." P3
I have learned to connect science to things which I had never thought they would connect to. P3
One has connected a lot of knowledge to one’s existing knowledge. P7
Learning occurred all the time more and more. P9
Learning depends on one’s own motivation and interest. P11

Learning styles were described by one’s own learning or in general terms.
I still like learning small things. P2
My learning style is traditional. P3
Exercises have been good, for testing myself – I learn best in this way. P5
The things to be studied one learns best just by familiarizing oneself with them in the nature and otherwise by practise. P11
I remember best the things the learning of which has been interesting and memorable. P11
In my opinion no other study method is as rewarding as an expert showing concretely what he has taught and telling about it at the same. P15

In summary, eleven views of seeing science teaching or learning science were found in the descriptions and they are shown in Table 17.

The students thought that instruction has to include inquiry (15 descriptions), studies have influenced their own action (7), their content knowledge has extended (5), instruction is hints for searching knowledge (4), a teacher has to be able to conclude, prepare lessons and accept that there are questions without answers (3), interests affect learning (3), technology gives new viewpoints for science teaching (3), emotional responses are important in learning (2), science is learning facts (2), the best teaching method is demonstration (1) and one student had learned a lot of difficult things but could not understand how to apply this knowledge at school. Thus the answer to the fifth research question in this part of the study “How do the students describe science instruction?” has been described.
<table>
<thead>
<tr>
<th>description</th>
<th>quantity</th>
<th>student</th>
</tr>
</thead>
<tbody>
<tr>
<td>...inquiry is important in instruction…</td>
<td>15</td>
<td>P1, P3, P5, P7, P10, P11,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P12, P13, P16</td>
</tr>
<tr>
<td>...studies have influenced my own action…</td>
<td>7</td>
<td>P1, P3 (2), P8, P9(2),</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P15</td>
</tr>
<tr>
<td>...the growth in content knowledge is important in learning…</td>
<td>5</td>
<td>P4, P5, P9, P13, P14</td>
</tr>
<tr>
<td>...hints for searching knowledge are important in teaching…</td>
<td>4</td>
<td>P3(2), P12, P13</td>
</tr>
<tr>
<td>...teacher has to learn to conclude, prepare lessons and accept that every</td>
<td>3</td>
<td>P7, P10, P16</td>
</tr>
<tr>
<td>question has not an answer…</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...interest affects learning…</td>
<td>3</td>
<td>P7, P10, P11</td>
</tr>
<tr>
<td>...technology gives new viewpoints for teaching science…</td>
<td>3</td>
<td>P3, P10, P11</td>
</tr>
<tr>
<td>...learning science is learning facts…</td>
<td>2</td>
<td>P2, P3</td>
</tr>
<tr>
<td>...emotions are most essential in learning…</td>
<td>2</td>
<td>P11, P12</td>
</tr>
<tr>
<td>...demonstrations are the best way to learn…</td>
<td>1</td>
<td>P15</td>
</tr>
<tr>
<td>...learned lot of difficult things, but not how to apply it at school…</td>
<td>1</td>
<td>P5</td>
</tr>
</tbody>
</table>

5.6.2 What are the students’ views of science instruction?

There are certain traditions and beliefs concerning the best way to teach and learn any given subject matter. These pedagogical traditions and beliefs, often implicit, are in turn transmitted to teachers student by the specialists. A teacher’s content knowledge has to include not just facts and concepts but also the structure of the discipline, its evolution, theoretical framework, and, finally, some knowledge of the history and philosophy of science. However, science teacher’s knowledge of the subject matter is different from that of a specialist, because a teacher relates the content to the process of teaching it. The teacher is the mediator who transforms the content into representations which are understandable by the pupils. Science teachers’ conceptions of science
and how to teach and learn it are the fruit of their own years in school, and are so deeply rooted that they do not always coincide with what would be most suitable way to do it (Mellado 1997). Primary school teacher students’ conceptions about good science learning in the study of Skamp and Mueller (2001) were making inquiries and hands-on experiments. Discovery learning seemed to predominate in the student teachers’ conceptions, with indications of a “positivistic” view of teaching. A “transmission” model of learning was not uppermost in the students’ minds. Hands-on activities had a role also among teachers’ beliefs in the study conducted by Levitt (2001). In her study she found out that teachers believe that the teaching and learning of science should be student-centred. Five patterns of teachers’ responses support the characterization of the teachers’ belief that the teaching and learning of science should be student-centred: engaging students in hands-on activities; students as active participants; learning personally meaningful; science education should foster positive attitudes; the role of the teacher changes to accommodate a focus on the students. Teachers espoused certain non-traditional beliefs about the teaching and learning of science. Secondary school teachers’ conceptions of teaching are categorized as (1) transmission of content/skills, (2) development of skills/understanding, (3) facilitation of understanding, and (4) transformation in the study of Boulton-Lewis et al. (2001). Respective categories for learning were acquisition of content/skills, development and application of skills/understanding, development of understanding and transformation. It must be noted that each teacher made statements about teaching and learning in their study which fell into more than one category but tended to have a dominant perspective. Later, besides these “positivistic”, “transmission” and non-traditional views, the views of science teachers’ beliefs of teaching and learning science have been categorized as either “traditional”, or “process”, or “constructivist” by Tsai (2002). The “traditional” category in his study perceives teaching science as transferring knowledge from teacher to students, learning science as acquiring or “reproducing” knowledge from credible sources. The “process” category perceives teaching science and learning science as an activity focusing on the processes of science or problem-solving procedures. The “constructivist” category views teaching science as helping students construct knowledge, learning science as constructing
personal understanding. These categories respond in some way to the modern view of science instruction described in the chapter 2 and the contemporary view of effective teaching and pedagogical approaches, too. STS orientation is seen to be one of these modern approaches.

After careful consideration of the students’ descriptions about instruction in the narratives it was found out that the categories of Tsai were quite suitable in this study too, but some changes and detailed structure were needed and they were taken partly from the categories described above. Contemporary (constructivist) view refers to a view, where teaching is seen as giving hints and learning is making inquiries, Process view is characterized as learning through inquiries. Traditional view refers to transmitting facts or content knowledge. The framework of categorizing students’ views of instruction is shown in Table 18.

<table>
<thead>
<tr>
<th>category</th>
<th>Tsai (2002)</th>
<th>this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>traditional</td>
<td>Science is best taught by transferring knowledge from teacher to students.</td>
<td>Teaching is transmission of facts or content knowledge.</td>
</tr>
<tr>
<td></td>
<td>Learning science is acquiring or ‘reproducing’ knowledge from credible sources.</td>
<td>Learning is receiving content knowledge.</td>
</tr>
<tr>
<td>process</td>
<td>Science is best taught by focusing on the processes of science or problem-solving procedures.</td>
<td>Teaching is arranging inquiries.</td>
</tr>
<tr>
<td></td>
<td>Learning science is focusing on the processes of science or problem-solving procedures.</td>
<td>Learning is conducting inquiries.</td>
</tr>
<tr>
<td>contemporary (constructivist)</td>
<td>Science is best taught by helping students construct knowledge.</td>
<td>Teaching is giving hints for the students.</td>
</tr>
<tr>
<td></td>
<td>Learning science is constructing personal understanding.</td>
<td>Learning is making inquiries and a change in action.</td>
</tr>
</tbody>
</table>

This framework of categorization corresponds to the three major types of teaching strategies commonly used in school science: the didactic approach, the process approach (discovery learning approach) and the constructivist approach (conceptual change approach). For learning the following categories; gaining knowledge, solving problem, and
constructing understanding, are used by Kobolla et al. (2000). For teaching their categories were transfer knowledge, problem posing and interacting with pupils, respectively, when they investigated gymnasium teachers’ conceptions of chemistry learning and teaching. These categories also reveal three philosophies of science. The “traditional” category is supported by empiricism and logical positivism; the “process” category is supported by naïve realism, while “constructivism” category is supported by a broadly constructivist philosophy (Tsai 2002) which, however, is not as rigorous in this study.

Table 19 shows three different student groups, their views of instruction and the key words in categorizing students’ views of instruction. For the three students who reflected in writing the narrative, teaching was an action to give hints and the best way to learn was making scientific inquiries. Also content knowledge and emotions were mentioned by these students. Two of the reflecting students highlighted inquiry. One student in the group of these reflecting ones valued demonstrations and another had no descriptions on instruction in her/his narrative. From the evaluating students two mentioned inquiry, and three students valued content knowledge. From the students, who mainly commented the education, one highlighted inquiry as a method, one saw content knowledge to be important and one saw facts as being typical for science.

In this study prospective primary school teachers’ descriptions of teaching and on the other hand of learning are considered as a view of science instruction. Students in this study also gave more than one description for teaching and learning and these descriptions are shown as keywords in Table 19. For example, student P3 describes teacher’s role as a giver of hints but at the same time facts are mentioned. Thus, contemporary view of science teaching is mixed with traditional view of learning. The contemporary description is chosen for categorizing. These mixed views are like those in the study of Kobolla et al. (2000). In their study qualitatively different conceptions of learning chemistry and teaching chemistry by prospective teachers were found. Each prospective teacher was found to hold more than one conception of learning chemistry and of teaching chemistry but one conception seems to dominate their perspective. They found the reproductive-oriented relationship between conceptions of learning chemistry as gaining knowledge and of teaching chemistry as transferring knowledge
supporting earlier investigations. Most of the primary school teacher students in this study showed uniform view of teaching and learning, in case they had described both views.

Table 19. Students' views of instruction found in the narratives

<table>
<thead>
<tr>
<th>student reflects</th>
<th>view of instruction</th>
<th>instruction is... (coding keywords)</th>
<th>quantity</th>
<th>student</th>
</tr>
</thead>
<tbody>
<tr>
<td>hints and inquiry (contemporary)</td>
<td>hints, inquiry, facts, change in own action and technology gives new viewpoints hints, inquiry, content knowledge hints, inquiry and emotional learning</td>
<td>7</td>
<td>P3</td>
<td></td>
</tr>
<tr>
<td>inquiry (process)</td>
<td>inquiry, emotional learning, interest, technology gives new viewpoints inquiry and teacher needs not to be besterwisser</td>
<td>4</td>
<td>3</td>
<td>P13</td>
</tr>
<tr>
<td>demonstration (traditional)</td>
<td>demonstrations, change in own action</td>
<td>5</td>
<td>P11</td>
<td></td>
</tr>
<tr>
<td>(traditional)</td>
<td>no mention on instruction</td>
<td>2</td>
<td>P16</td>
<td></td>
</tr>
<tr>
<td>student evaluates</td>
<td>inquiry (process)</td>
<td>inquiry, teacher's role, interests, technology together with science inquiry, teacher's role, interests</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>content knowledge (traditional)</td>
<td>learning content knowledge, change in action learning content knowledge learning content knowledge</td>
<td>3</td>
<td>1</td>
<td>P9</td>
</tr>
<tr>
<td>content knowledge (traditional)</td>
<td>inquiry (laboratory work), change in own action change in own action</td>
<td>3</td>
<td>P1</td>
<td></td>
</tr>
<tr>
<td>student comments</td>
<td>inquiry (process)</td>
<td>inquiry, learning content knowledge, learned not apply</td>
<td>2</td>
<td>P5</td>
</tr>
<tr>
<td>facts (traditional)</td>
<td>facts</td>
<td>1</td>
<td>P2</td>
<td></td>
</tr>
</tbody>
</table>
Finally, the connections between the students’ views of instruction and learning and the theoretical framework of Science and Technology Education is drawn from the research results in Table 19 and the results are shown in Figure 7.

Figure 7. Students’ views of science instruction and instruction methods respectively placed in the rote-meaningful and Science and Technology Education continuum.

One of the reflecting students in the lower left-hand side corner is the student who did not write about science or science instruction in the narrative and thus her/his view is undefined. As it can be seen in Figure 7 half of the students under consideration are set in the triangle which responds to the views at the background of Science and Technology Education. Thus, these students have probably absorbed those pedagogical ideas which are seen essential in the education. The other half of the students has seen the science instruction more as rote learning and reception discovery. From the viewpoint of the aims of the education this result is satisfactory but not good enough. Developmental work is still needed to help more students to adopt the contemporary view of STS instruction.
5.6.3 Concluding remarks on students’ views of instruction

Traditionally, learning of answers, memorizing bits and pieces of information, recitation, and reading are emphasized in science classes at the expense of exploration of questions, critical thought, understanding in context, argument, and doing science. In the traditional model, it is assumed that an already developed body of knowledge, generally accepted by the scientific community, can be transmitted to students through passive instructional means. Instead, constructivism acknowledges that what really matters is the knowledge already in the learner’s mind. A child’s experiences from his or her environment form her/his knowledge base and profoundly effect the child’s view as a learner of the world and his or her ability to accept other more scientifically grounded explanations. Learning in science is more a matter of altering prior conceptions than giving explanations where none have existed before. Children’s learning in science may be better characterized by changes in their thinking rather than additions to their thinking. The process is evolutionary; students constantly “revise, reorganize, and deepen understanding” as they are exposed to new information. (Levitt 2001.)

To advance the restructuring of students’ knowledge, the role of the teacher moves from a transmitter of knowledge to a guide and a facilitator in the students’ construction of knowledge. This role does not appeal to all teachers. If teachers do not believe philosophically in teaching as understanding, but rather as dispensing information, this role will be rejected. In this study primary school teacher students had different views of science teaching and learning. The views were traditional, process or contemporary views. Three students who had adopted the reflecting viewpoint to the writing of the narrative had contemporary view of instruction. Two of the reflecting students had process view of science instruction as also two of the students who had adopted the evaluating viewpoint to the writing. Three students of the reflecting students had traditional view as also three of the evaluating students and two of the commenting students. Thus the finding of these three categories agrees with that of Kobolla et al. (2000) and Tsai (2002).
Elementary teachers hold three themes of the beliefs: engaging students in hands-on activities; students as active participants in learning science; the learning of science should be personally meaningful to students, as Levitt (2001) has stated. For the majority of teachers in each of the three categories, the primary goal for science instruction was the development of positive attitudes toward science. In her study teachers did espouse certain non-traditional beliefs about the teaching and learning of science as a contrast to prior research, but which statement this research supports. Prospective science teachers in Levitt’s study had two kinds of beliefs concerning constructivist teaching practices: central beliefs and peripheral beliefs. The central beliefs were defined as dictating subsequent teaching behaviors; whereas the peripheral beliefs were those that were stated but not operationalized.

Contemporary view in this study was certainly caused by the pedagogical studies, which the students had performed before Science and Technology Education. Obviously the students had learned the theories of the modern view of instruction, which learning had reinforced during the courses of discussing science pedagogy and STS-education. Process view seems to result from the science pedagogy lectures in Science and Technology Education, but also from the physics practises in the entity, where the inquiries as a working method for science were strongly preferred. Traditional view can be seen to date back to the school days. It is hard to believe that the students would have adopted traditional view from the teacher education program which strongly emphasizes modern view of teaching and learning. This shows that it is hard to change students’ views or preconceptions which they bring with them when entering the teacher education. The sixth research question concerning students’ experiences “What are their views about science instruction?” has now been clarified from the narratives.
5.7 Connections between students’ views of science and science instruction

When comparing the descriptions of each individual student about science and about instruction it was found out that for reflecting students, good science instruction could be of making inquiry and giving hints (Table 20). The view of science was a combination of contemporary and practical view or of pedagogical and practical view. For evaluating students the view of science was a combination of pedagogical and practical view. The students who only commented education did not write about science or scientific knowledge. Although the students’ views of science are multidimensional after considering descriptions of different disciplines the view of science seen through science descriptions is used in the following condensation of the data. The view of science has, however, stayed close to the found category also after the more exact consideration with descriptions of the disciplines.

The primary teacher students had, after Science and Technology Education, quite different views science. Four of them had a contemporary view of science and two of them still had a traditional view of science. Five of the students had a practical view of science as they saw science to be close to everyday life. Three of the students highlighted pedagogy. The primary teacher students thought also that good science instruction is making inquiries, a teacher has to give hints and the role of a teacher is important, thus, the teacher students had quite contemporary views of science instruction. This is mainly caused by the pedagogical studies where the students had learned the modern learning theories. However, the influence of Science and Technology Education is seen also in the stories, when the students wrote about changes in their thoughts or action. Some of the students had, however, more traditional view of science instruction and they highlighted content knowledge or even facts.

There were different relations between views of science and views of science instruction. Only those students who reflected the education had a contemporary view of science. In most cases they had also a contemporary view of science instruction. A student had most often the traditional view of science instruction, when s/he had not written any descriptions about science or scientific knowledge. The students had more frequently the view of science instruction than the view of
science, which is probably due to the fact, that they study education
as their major subject and science as the third or fourth minor subject.
Their viewpoint is of course the viewpoint of the prospective teacher.
Their goal in every education is to learn to teach. The situation is
described also in Figure 8 to realize better the relations between the
views of science and the views of science instruction.

Table 20. Students' views of science and of science instruction found
in the narratives

<table>
<thead>
<tr>
<th>student group</th>
<th>student</th>
<th>view of instruction</th>
<th>view of science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflects</td>
<td>P3</td>
<td>hints and inquiry, contemporary</td>
<td>contemporary and practical</td>
</tr>
<tr>
<td></td>
<td>P12</td>
<td>hints and inquiry, contemporary</td>
<td>contemporary, pedagogical and practical</td>
</tr>
<tr>
<td></td>
<td>P13</td>
<td>hints and inquiry, contemporary</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>P11</td>
<td>inquiry, process</td>
<td>contemporary and traditional</td>
</tr>
<tr>
<td></td>
<td>P16</td>
<td>inquiry, process</td>
<td>contemporary and practical</td>
</tr>
<tr>
<td></td>
<td>P15</td>
<td>demonstrations, traditional</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>P6</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Evaluates</td>
<td>P7</td>
<td>inquiry process</td>
<td>pedagogical and practical</td>
</tr>
<tr>
<td></td>
<td>P10</td>
<td>inquiry, process</td>
<td>pedagogical and practical</td>
</tr>
<tr>
<td></td>
<td>P4</td>
<td>content knowledge traditional</td>
<td>traditional</td>
</tr>
<tr>
<td></td>
<td>P9</td>
<td>content knowledge, traditional</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>P14</td>
<td>content knowledge traditional</td>
<td>no</td>
</tr>
<tr>
<td>Comments</td>
<td>P5</td>
<td>inquiry, process</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>P1</td>
<td>content knowledge, traditional</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>P8</td>
<td>content knowledge, traditional</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>P2</td>
<td>facts, traditional</td>
<td>no</td>
</tr>
</tbody>
</table>
Figure 8. Relations between the students’ views of science and the views of science instruction seen through science descriptions.

The most relevant results on the views can be summarized as follows. There is a tendency that views of science and views of science instruction relate. The students who have a contemporary view of science have a contemporary view of science instruction too, and vice versa the students who have no view of science or have a traditional view of science, have a traditional view of science instruction, too. Whereas when also the descriptions of different disciplines are taken into account, the situation changes a bit (Figure 9). Figure 9 reinforces the finding of the relation between these two views.

Figure 9. The relations between the students’ views of science and the views of science instruction when descriptions of different disciplines are taken into account.
The students’ views of science have moved towards more contemporary view when considering different disciplines. However, the tendency that more contemporary view of science means also more contemporary view of science instruction is clear. This contrasts with the finding of Roth and Roychoudhury (1994) that at the same time as students have a traditional view of science they could view learning differently, which may be the product of different learning environment of the physics course in the context of their study. In this study results about views can be seen to be similar to the work of Wolf-Watz (2000) even though the students are seen from another viewpoint. Student teachers in Sweden had themselves an awareness of their own role, which they brought to school and their future work. The students in the study of Wolf-Watz saw science primarily as applied knowledge. But they were aware of the importance of teachers’ knowledge in and about science in order to make science teaching and learning more effective. In this study the students did seldom state directly the relation between thoughts on science and on science instruction, but the tendency that these views relate is found in the comparison of the views during the analysis. Anyway the relations are very complex and students hold different kinds of view combinations. These results about relations agree with the results of Tsai (2002) of science teachers' beliefs of teaching, learning and science. Tsai calls the observed relations nested, related and divergent. In his study nested relationship means that teachers have congruent beliefs about teaching, learning and science. In this study descriptions about teaching and learning are handled together as on entity called instruction. The students’ descriptions about both were congruent. Related relationship in Tsai’s study means relation between teaching and learning, between learning and science, or teaching and science. Most of the teachers had either nested or related belief system. In this study about half of the students’ had similarly related views. Divergent system in Tsai’s study indicates to absence of relationships between teaching, learning or science. Contrary to this study, only few of the teachers had divergent belief system. But I must remind the reader that even though the view was not found, it does not necessarily mean that the students did not have a view, they only did not describe it.

The students in this study show more contemporary view of science instruction than reported for example in the study of Tsai (2002). In this study the prospective primary teachers do not see a teacher as a
presenter of the factual content of scientific knowledge and transferring knowledge to students. The fact, that many teachers hold traditional views of teaching science, learning science, and the nature of science, may stem from the problem of their own school science experiences. The science classes, laboratory exercises, relevant activities in teacher education and Science and Technology Education in the context of society and technology and the nature of science have not reinforced the traditional views, but shown an alternative view, which the students have adopted. How these primary school teacher students behave in their future classroom is another question. Do their contemporary view of science and science instruction influence their classroom behaviour? Teachers’ conceptions of science do not necessarily influence classroom practice (Lederman 1999). There is a difference between beginners and experienced teachers. The most experienced teachers exhibit classroom practices consistent with their professed views about the nature of science. In Ledermans’ study one of the experienced teachers did not teach in a manner consistent with her view of science. It was noticed also that unless a teacher clearly intends to address the nature of science and follows through with explicit emphasis during instruction, students will not develop an understanding of the nature of science that happens to be consistent with the organization of a particular lesson or activity which contradicts the research of Palmquist and Finley (1997). Preservice teachers’ conceptions about teaching and learning science and their classroom behaviour did not have correspondence in the inquiry of Mellado (1997, 1998) either. How can we change Science and Technology Education to help the other part of the students to change their views of science and science instruction toward more contemporary view in order to help them to understand sciences? “Are the students’ approaches to learning science influenced by their views of science?” — the seventh research question has now been answered.
5.8 Summary of narratives

Primary school teacher students wrote in their narratives of their Science and Technology studies during one academic year, comments about different courses, reflected their own studying and evaluated their education. Those students, who reflected or analyzed mostly their own action, had quite contemporary views of science and science instruction. They were familiar with the modest science instruction principles and thought, that science teaching is about giving hints and the teacher is a guide. Studying science is searching information and making inquiries. These students respected their science education and the context of technology and society. They described changes in their thoughts or action due to Science and Technology Education.

Those students who evaluated education in their narratives gave both positive and negative assessment. They were satisfied with the education, but did not understand or accept all the pedagogical solutions of the education. These students would like to have more “cookery book” instructions for the science teaching. Their view of science and science instruction was less contemporary than that of the reflecting students. They did not reflect their own thoughts, learning or action, but instead of that of the teachers’ of Science and Technology entity.

The third group of students in this study was the commentators. In their narratives they commented neutrally the education by telling what happened and when. They did not reflect their own studying, thoughts or action. They also liked the education, but would have liked to have more direct hints for their future teacher profession. For them science is more than for others about remembering facts. Their view of science was mainly traditional.

Almost all students wrote about science, scientific knowledge, science teaching and science learning. They wrote at a general level. They did not write about different learning methods or principles typical for science, which had been discussed during the education. Inquiry was seen by most of the students as the most important way to study science. Demonstration was described once. The students’ views of science and of science instruction were multidimensional. These views seemed generally to relate with each other.

It has been reported in the literature that teacher students have mixed views of science. These views are between traditional and
contemporary (or constructivist) views of the nature of science and scientific knowledge (Palmqvist and Finley 1997; Murcia and Schibeci 1999; Haidar 1999). Recently Tsai (2002) has reported three types of epistemologies that students have, and the results of this research follow the same line. In this study the aim has not been to find the conceptions of scientific knowledge, but rather to find out the view of science, which students have. The research method and the use of the narratives are different from the earlier studies, which have generally used questionnaires including statements of the scientific knowledge. By interpreting the narratives the results, which are in agreement with the earlier studies, were found.

One of the narratives was very different from the others. This narrative was more of a story with imaginary features. A student wrote about her/his relation to nature. The reader must be reminded that as the students in this study had chosen the education freely they had some interest to science prior to the studies. Some descriptions in their narratives, however, expressed clearly that students had taken the education because they had had space in their lesson plans.

"The grown-ups, to be sure, will not believe you when you tell them that. They imagine that they fill a great deal of space. They fancy themselves as important as the baobabs. You should advise them, then, to make their own calculations. They adore figures, and that will please them." (Antoine de Saint-Exupéry: The Little Prince)
6 How did the students change?

The third research area in this study deals with the relations between the students’ views of science and of science instruction and the students’ use of knowledge type either the use of everyday knowledge or scientific knowledge. In the first part of the study the explanations of the physics phenomena were considered and it was found out that the students used mainly everyday knowledge in their explanations, but the scientific knowledge increased slightly towards the end of the education. In the second part the views of science and of science instruction were found from the narratives students had written.

In the narratives the students described the changes in their own action or thoughts 42 times. These descriptions were connected to the students themselves. Typical descriptions concerning science instruction were.

I still like learning "small" things just like in the upper secondary school. P2
I have noticed how important it is to be able to search knowledge. P3
I feel that I now have got confidence in my own teaching. P6
I do not think anymore that everything should be in my head. I am able to search for the required knowledge instead. P3

Descriptions concerning science were also written.

Then I started to think of scientific subjects as topics supporting each other. This conception has still been reinforced in my vocational studies, where the teaching has pointed out the connections between things. Also, with my minor studies I have been able to widen further my scientific view. P3
I got the conception of the entity from the contents of the discipline. P9
Immediately at the beginning of the education the motivation to study science aroused in me. P7
I think in a more investigative way. P10
Bias knowledge, which has been reinforced during the course, has sometimes even changed entirely. P13

The students clearly described changes in their thoughts or action. Most of the students got more interested in science during the education than they had been before the education. The students told that they were no more afraid of the science teaching, expressing that
they had been afraid of science teaching earlier. One of the students still liked learning small things, facts, as s/he had done earlier in the upper secondary school. And one of the students told that her/his scientific view had expanded. Changes expressed by the students mostly concerned thoughts on science and on science teaching. It can be interpreted that the students’ views of science and of science instruction have changed towards more contemporary view. However, all students did not describe these changes. The change during the education was not the only reason for the views described in the preceding chapter. Rather, the students had had these views before the education and there had been a small shift in their views.

The change in the ways how the students explained physics phenomena is shown in Table 6 in chapter 4. They explained most of the phenomena by using everyday knowledge and a small increase towards using the scientific knowledge was observed after the education. These changes will now be compared with the students’ views of science and views of science instruction (Table 21).

Five of the seventeen students (P1, P2, P9, P10, and P15) had not left the other of the two explanation formulas concerning physics phenomena, and one student (P17) had not written the narrative, thus, consequently, the number of the students under consideration is now eleven in the following consideration. As expected those students who had learned to use more scientific concepts and scientific ways to explain got excellent or good marks in the exam (P5, P7, P8, P11, P14, P16). The mark was got in the physics exam which contained five questions about the topics which were dealt in the course. However, one student (P12) who had not used more scientific explanations at the end of the education than s/he had used in the beginning still got an excellent mark in the exam. The student who did not change her/his way of explaining got the lowest mark. It also seems that the students who had either a contemporary view of science or of science instruction got excellent marks. Also, a pedagogical or practical view of science and process view of science instruction seem to relate to excellent marks. An exception is now one student (P14), who learned to explain in a more scientific way, got excellent marks, but did not show any view of science and traditional view of science instruction. Those students who got good marks without showing contemporary view of science or science instruction had probably “learned the contents by rote”. This is unfortunately very common in our schools and was now
possible in our education, too. These findings are consistent with the research findings in the literature that indicate that learners’ views of the nature of science are not significantly related to their science content knowledge (see Akerson et al. 2000). For me as a teacher this observation means that I have to develop tests which demand understanding rather than remembering.

Table 21. The change in the knowledge type and views of science and of science instruction.

<table>
<thead>
<tr>
<th>student</th>
<th>net positive changes</th>
<th>view of science</th>
<th>view of science instruction</th>
<th>marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>reflectors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P16</td>
<td>+++ +++ +++ +++</td>
<td>contemporary</td>
<td>process</td>
<td>excellent</td>
</tr>
<tr>
<td></td>
<td>+++</td>
<td>and practical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P11</td>
<td>+++ +++</td>
<td>contemporary</td>
<td>process</td>
<td>excellent</td>
</tr>
<tr>
<td></td>
<td>+++</td>
<td>and traditional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P6</td>
<td>+++</td>
<td>no</td>
<td>no</td>
<td>good</td>
</tr>
<tr>
<td>P13</td>
<td>+++</td>
<td>no</td>
<td>contemporary</td>
<td>good</td>
</tr>
<tr>
<td>P3</td>
<td>++</td>
<td>contemporary</td>
<td>contemporary</td>
<td>good</td>
</tr>
<tr>
<td></td>
<td>++</td>
<td>and practical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P12</td>
<td>0</td>
<td>contemporary</td>
<td>contemporary</td>
<td>excellent</td>
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<tr>
<td></td>
<td></td>
<td>pedagogical</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>and practical</td>
<td></td>
<td></td>
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<tr>
<td>evaluators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P14</td>
<td>+++ +++ +++ +++</td>
<td>no</td>
<td>traditional</td>
<td>excellent</td>
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<tr>
<td></td>
<td>+++</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P7</td>
<td>++</td>
<td>pedagogical</td>
<td>process</td>
<td>excellent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and practical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>0</td>
<td>traditional</td>
<td>traditional</td>
<td>passed</td>
</tr>
<tr>
<td>commentators</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>P5</td>
<td>+++</td>
<td>no</td>
<td>process</td>
<td>good</td>
</tr>
<tr>
<td>P8</td>
<td>+++</td>
<td>no</td>
<td>traditional</td>
<td>good</td>
</tr>
</tbody>
</table>
In the following Figures models for different types of students are shown in the form of concept maps. I will remind the reader that there may be an oversimplification of the multidimensional situation. However, five types of students' views and their relations have been found. Firstly (Figure 10), there is the model for a student with a contemporary view of science and science instruction. S/he has spoken of both things. Thus her/his views relate to each other and to the enhancement of the scientific knowledge during the education. This student is a reflecting student.

![Diagram](image)

**Figure 10.** The model of relations in the case of a reflecting student with contemporary views

The model for a reflecting student with a more complicated view structure is shown in Figure 11. This student has also written about science and science instruction. Her/his view of science is a process view and in science instruction both contemporary and practical views exist. These views relate, but are in no way in contradiction. The use of scientific knowledge has increased during the education. Another student (P12) has a similar view structure, but her/his scientific knowledge has stayed at the same level after the education.
Figure 11. The complicated model of views and their relations in the case of a reflecting student with contemporary, practical and process views

The third type of view structure for reflecting students is shown in Figure 12. This type of student has not written about science or science instruction, thus s/he has not found it important compared to other things which s/he has highlighted. Her/his use of scientific explanations has, however, increased during the education. One reflecting student (P11) has a similar view structure as also has one evaluating student (P7).
Figure 12. The simple model of views and their relations in the case of a reflecting student

Fourthly, the evaluator (P4, Figure 13) represents a student who has written both about science and science instruction and her/his views have been analyzed to be traditional. Thus the views relate. The student’s scientific knowledge has not enhanced during the education.

Figure 13. The model of views and their relations in the case of a evaluating student with uniform traditional views
Finally, the model for a commenting student who has written about science but not about science instruction is shown in Figure 14. Her/his view of science is a process view and her/his scientific explanations have increased during the education. One reflecting student (P13), one evaluating student (P14) and another commenting student (P8) have the similar view structure, but the views are contemporary, traditional and traditional, respectively.

![Diagram](image)

**Figure 14.** The model of views and their relations for students, who did not write about science

To sum up, firstly, the linkage between the students’ views of science and science instruction seems to exist. Secondly, the traditional view of science or of science instruction seems to relate to poor adoption of scientific explanations, and the more contemporary view of science seems to relate to enhancement of scientific knowledge. The relations between the views of science, views of science instruction, and learning of scientific explanations are very multidimensional. The beforementioned tendencies can be found, but it would be an oversimplification to conclude that the students in this study would only have one type or two types in their views. It is evident that it is
reasonable to expect understanding of science from those students with contemporary views of science and science instruction. Respectively, the students with traditional views rather learn by rote.

Although the relationships between the views of science and of science instruction have been somewhat investigated in the literature, the relations to learning results in the same investigations have been less studied. The importance of understanding the influence of the nature of science to learning results has been widely studied, but in other contexts. During the process of this work a study by Davis (2003) which connects the views of scientific knowledge and understanding of science was published. She noticed in her study that middle school students who see scientific knowledge as dynamic, with decisions about that knowledge made on the basis of evidence, are likely to view understanding as the best strategy for science learning, and vice versa, which findings this research agrees with based on the views of the primary school teacher students. Students who see science as a collection of static facts are more likely to view memorization as the best strategy for learning science as seems also to be the situation in this study. In some cases it seemed, unfortunately, to be a successful strategy by the primary school teacher students in my exam, too. It has been demonstrated that STS group students performed better in terms of the extent, richness and connection of cognitive structure outcomes than did traditional group students (Tsai 2000). STS instruction has been especially beneficial to those students with epistemological views more oriented toward constructivist views of science. This leads me to presume that there may be a connection between STS instruction and the views of science and STS instruction and the performance in the physics exam, too. The students described little STS instruction, they told more about inquiries, so it is not possible to make any conclusions about the influence of STS instruction to students’ views of science or to their cognitive outcomes. In the STS oriented education students have been found to perceive that the classroom environments improved in terms of personal relevance of contents, scientific uncertainty and student participation (Cho 2002). STS instruction had positive impacts especially on female students’ cognitive structures in the study of Tsai (2000). This finding supports our aims to apply STS orientation further in the science instruction of primary school teacher students who are mainly females.
The last research question “How are the students’ views of science and of science instruction related to the knowledge types that students use?” has been tried to work out. Some simplifications of the situation are made, but it has to be remembered to bear the multiplicity of the situation in mind.

“But it happened that after walking for a long time through sand, and rocks, and snow, the little prince at last came upon a road. And all roads lead to the abodes of men.

“Good morning,” he said.

He was standing before a garden, all a-bloom with roses.

“Good morning,” said the roses.

The little prince gazed at them. They all looked like his flower.

“Who are you?” he demanded, thunderstruck.

“We are roses,” the roses said.

And he was overcome with sadness. His flower had told him that she was the only one of her kind in all the universe. And here were five thousand of them, all alike, in one single garden!” (Antoine de Saint-Exupéry)
7 General discussion and evaluation of the study

The primary purpose of this study was to contribute deep understanding on primary school teacher students’ thoughts on their Science and Technology Education and on science in general. The analysis of the data led to deeper consideration of the students’ views of science and science instruction. The research process has been collated into the Vee heuristic (Figure 15). Even though all the educational tools in this study to help in the organization of the material are not enclosed in the report, the Vee heuristic as a conclusion is well appropriate. A heuristic is something employed also as an aid to understanding a procedure. The concept maps in the preceding chapter served for the same purpose. The Vee heuristic grew out of a twenty-year-search by Gowin for a method to help the ways in which humans produce knowledge, and evolved from a scheme for “unpacking” the knowledge in any particular field (Novak and Gowin 1990, 55). The Vee helps us to see that although the meaning of all knowledge eventually derives from the events and/or objects we observe there is nothing in the records of these events or objects that tells us what the records mean. This meaning must be constructed, and we must show how all elements interact when we construct new meanings. The left-hand side of the Vee serves as a thinking side and the right-hand side as a doing side. The Vee heuristic is a tool for acquiring knowledge about knowledge and how knowledge is constructed and used. The Vee heuristic helps to see the interplay between, what the learners already know and the new knowledge they are producing and attempting to understand. It should be evident that such a heuristic has psychological value because it not only encourages meaningful learning but also helps learners to understand the process by which humans produce knowledge. (Novak and Gowin 1990, 56-57, see also Novak 1998, Åhlberg 1996). I hope that in this case the Vee helps also the reader of this report as a learner to understand the process by which I have produced the knowledge. I am also well aware of the fact that both the concept map and the Vee heuristic are in this case somewhat simplified tools and may simplify the knowledge and the process of the study too much, but I count on that the reader familiarizes her/himself also the preceding chapters of this report to get more multifaceted view of the study.
1. Research task: How do primary school teacher students experience science?

2. Why use my time for this research? As a teacher, I have to understand my students' ideas to be successful in instruction. I am also curious by my nature.

3. What do I think about students' experiences and science education? I believe that students have some kind of background knowledge acquired in informal learning and during the schooling time. I agree with the constructivist framework and the principles of STS education, but I also acknowledge content knowledge and believe in learning by doing.

4. What are the relevant concepts for this study? This study needs concepts learning in everyday situations, science education, STS-education, case study, discourses, and narratives. Methodological framework and solutions of the inquiry.

5. Which methods do I use in my research? I rely on the naturalistic case study in the context of Science and Technology Education. The data is collected empirically in the form of discourses and narratives. Methodological framework and solutions of the inquiry.

6. How is the research implemented? The data is collected during the academic year of 1999-2000. The main data was acquired in the spring 2000. The subjects of the study were the students participating in Science and Technology Education during that academic year. The students explained physics phenomena and wrote a narrative about their science studies. The analysis of this written data was data-based. Methodological framework and solutions of the inquiry.

7. What kind of data I get? Narratives were diverse. I found descriptions about 26 different themes. I feel that I have got certainty in my own teaching P6. Discourses were short explanations for the phenomena: The temperature tends to smooth. More warm air BP1, Students' explanations in physics phenomena and Students' experiences.

8. How did I find the results out of the data? Narratives and discourses are coded. Coded explanations were categorized, thematized and typologized to find some similarities and/or differences. Students' explanations in physics phenomena, Students' experiences and How did students change?

9. What are the main results? There was no special language which was typical for the primary school teacher students. The students explained physics by using everyday and scientific knowledge. The students had three different ways to write about studies. They reflected, evaluated or commented. Their views of science and science instruction were different ranging from traditional to constructivist views. The view of science influenced on view of science instruction. View of science instruction influenced on an understanding of physics. Students' explanations in physics phenomena, Students' experiences and How did students change?

10. How important is the new knowledge for me? The results are important for understanding each other and to develop education. General discussion and evaluation of the study.

Figure 15. The research process carried out in this work
During the last three decades beliefs, views and images of science and also science teaching and learning have been studied widely in other continents but less in Europe revealing the teacher students’ and younger pupils’ limited conceptions of the nature of science. As a consequence of these findings, during the last three years studies in science education have focused also on the relations between views of science and learning results after intervention, in which the changes in the students’ understanding have been assessed. These studies have earlier mainly been conducted from a quantitative and more recently from a qualitative, interview and questionnaire, viewpoint. After reviewing a vast number of quantitatively oriented studies dealing with the nature of science, Lederman et al. have in their speech, according to Moss (2001) concluded: “We have taken paper and pencil assessments about as far as they can be expected to go.” They encourage the science education community to make use of a variety of methodologies to assess individuals’ understanding of the nature of science, which Moss strongly supports. The studies of views of science have focused on earlier school years, on teachers and on pre-service science teachers, whereas in this study the experiences of science education is considered in Science and Technology Education context in the primary school teacher education. Recently, some studies have started to consider views of the nature of science to be included in the intervention (e.g., Abd-El-Khalick 2005). The framework in which the views, beliefs or images are discussed has been similar in the sense of modern conception of science education. However, they have differed in the definitions of the features of the nature of science. These studies have been carried out in different cultures. In this study the views have been seen widely concerning any feature of science or science instruction. The research framework focuses not only on views, but also experiences during the education. However, Kobolla et al. (2000) agree that finding similar categories in different countries with different cultures and educational systems gives support to the claim that there exists a finite number of ways in which learning and teaching are conceptualized.
7.1 Evaluation of the research process

The research was carried out in a teacher education context in which students studied science in the context of technology and society. The study was carried out in two separate parts, which parts had different goals. In the first part student teachers’ explanations in physics phenomena were discussed to find out their ways to of explaining physics. The other part consisted of the narratives, which the students had written after Science and Technology Education. Finally, the findings of these two parts were connected to find out the possible relationships between explanations and views of science and science instruction, and students performance in physics, too. Explanations were considered as discourses and writings as narratives, and their analysis was done data based. It is worth questioning whether the results would have been similar if the studies had been conducted in a different way by using tested questionnaires. For this question more research will be needed if idealistic and controlled results are needed. For educational practise in the context of Science and Technology Education this is not so important. From the view point of the context, none of the tested questionnaires could take into account the situation in which the study has been carried out. It is undoubtedly clear that the teacher and the instructional process have an effect and consequently this study especially can be seen as situational. In this research the case study has been conducted in natural settings, without designing or controlling the teaching during the education for the research purposes, and in that sense the teaching approach itself has not been researched, but an influence to students’ thinking has.

In this study, firstly, the language which primary school teacher students use in explaining physics phenomena, has been clarified. Reasoning has been studied before and after the physics instruction. The ways to reason have been discussed through qualitative dimensions of reasoning based on the empirical data and previous research. The types of knowledge which the students used have been captured, although in the case of some students the interpretations remain limited and weak. The changes in the explanations have also been clarified. For deeper analysis a multiphase data gathering period would have been needed starting from the entrance to the university and ending at the practises at schools.
Secondly, the experiences of the primary school teacher students during Science and Technology Education have been discussed to reveal those actions and experiences which have been significant for the students. This approach has been seen relevant to capture the students’ own thinking concerning education. The results from the first phase of the narrative analysis have been led in this study to consider the students’ views of science and science instruction. The views have been analysed based on the data, and views of science and of science instruction have compared. For wider interpretations, an interview would have been needed. It is seen as a challenge for further studies. However, unlike in previous studies, in this study the two parts have been discussed in order to try to formulate a coherent picture of the students’ views in the natural contexts.

In this section the evaluation of the research design, data gathering, and data analysis have been discussed from the viewpoint of the research results. Qualitative research and especially case studies often come under criticism as unreliable and invalid ways of conducting research. However, many educational research interests are involved with questions which are not appropriate to approach by using quantitative research methods. This study is seen to belong to those researches. In addition, the criteria which are appropriate for judging the goodness or quality of an inquiry have been proposed in different ways in qualitative research compared with quantitative research. In qualitative research the following four alternatives reflect faithfully the assumptions behind this inquiry. The trustworthiness of the study from the viewpoints of the theoretical commitments, study design and research methods are asserted next by the following criteria: authenticity – the trustworthiness criteria of credibility (paralleling internal validity); transferability (paralleling external validity); dependability (paralleling reliability); confirmability (paralleling objectivity).

**Authenticity**

Authenticity means the internal validity of the research, according to which the “threats” to the trustworthiness are assessed. Qualitative researchers have to question seriously the internal validity of their work (Ward Schofield 2002). Other researchers reading their field notes would feel the evidence do support the way in which they have depicted the situation. However, they do not expect other researchers in a similar
or even in the same situation to replicate their findings in the sense of independently coming up with a precisely similar conceptualization. As long as the other researchers’ conclusions are not inconsistent with the original account, differences in the reports would not generally raise serious questions related to validity or generalizability. However, any piece of qualitative research is likely to contain so many individual descriptive and conceptual components that replicating it on a piece-by-piece basis would be a major undertaking. (Ward Schofield 2002, 174.) The study findings have to make sense for the people involved in it, as participants, researcher or reader.

The main issue for the trustworthiness of the study is internal validity, which focuses on the questions of the consistency of the findings. In this study to increase the internal validity and therefore authenticity the context has been emphasised in describing it suitable and the study design has been set in terms of the context in which the study has been carried out. The plausibility and integrity of the research has been made explicit by giving authentic data and interpreting this data in a transparent manner. To decrease the misunderstanding of the authentic data and the interference of language translation in some authentic examples both languages (English and Finnish) have been used. To increase the internal validity of the research findings the context has been described in detail and my own role as a researcher has been made explicit. In addition, the codes of data have been used as a basis for the categorization systems and thus the results represent the current data completely. The interpretations of data have been linked to the theoretical discussion and to previous studies. The cases have been used as a tool to focus on the views of science and science instruction and the knowledge change and in a holistic manner using embedded study design of case studies.

In the current study the qualitative dimensions of the students’ explanations and views based on the different data sources have been identified. Explanations as a discourse and narratives offered a way to consider the knowledge types and the view type of each student. To increase the validity of the interpretations for further studies interviewing based on the narratives has been advocated, to make the analysis process of the students’ views more valid and deep. The students used a lot of short explanations and descriptions and, thus, for understanding the students’ thoughts it is necessary to define the
students' writings by complementing them with interviews. When it has been decided to concentrate on views of science and science instruction, it would have been useful to ask the students directly about their thoughts on these subjects. The lack of the interview material can be seen as a methodological weakness of the study, although it did not cause insuperable problems in answering the posed questions. And narrative theorists disagree on the importance of the interview context (Kohler Riessman 2002, 233). In storytelling a teller has a fundamental problem: how to convince a listener who was not there when something important happened. Narratives are interpretive and, in turn, require interpretation. They do not "speak for themselves", or "provide direct access to other times, places, or cultures". It is always possible to narrate the same events in radically different ways, depending on the values and interests of the narrator. There is no reason to assume that an individual's narrative will, or should be, entirely consistent from one setting to another.

There are at least four ways of approaching the validation in a narrative work: persuasiveness, correspondence, coherence, and pragmatic use (Kohler Riessman 2002, 258). Persuasiveness is greatest when theoretical claims are supported with evidence from informants' accounts and when alternative interpretations of the data are considered. The criterion forces to document interpretive statements for the benefit of sceptical outsiders. (Kohler Riessman 2002, 258.) In this study students' views found in the narratives support earlier claims and also alternative interpretations (categories) of the data have been found. Pragmatic use refers to the extent to which a particular study becomes the basis for other work. This criterion is future oriented, collective, and assumes the socially constructed nature of science. I believe that this work will continue in similar studies.

Transferability

Many qualitative researchers actively reject generalizability (external validity) as a goal, or many give it very low priority or see it as essentially irrelevant to their goals (Ward Schofield 2002). Numerous characteristics that typify the qualitative approach are not consistent with achieving external validity as it has generally been conceptualized. Yet, at the heart of the qualitative approach there is the assumption that a piece of qualitative research is very much influenced by the
researcher’s individual attributes and perspectives. The goal is not to produce a standardized set of results that any other careful researcher in the same situation or studying the same issue would have produced. Rather it is to produce a coherent and illuminating description of and perspective on a situation that is based on and consistent with detailed study of that situation. (Ward Schofield 2002.) Under transferability Lincoln and Cuba (2002) state that transference can take place between contexts A and B if B is sufficiently like A on those elements or factors or circumstances that the A inquiry found to be significant. In order to make that judgment possible for a reader, "thick description" is needed, not in the sense of long and detailed descriptions, although that may be necessary, but in the sense of making clear levels of meaning (Lincoln and Cuba 2002). Although this study is a naturalistic case study it should have some implications and power of transferability to other contexts. The case itself is unique and has characteristics which cannot be repeated, but the phenomena under investigation and the interpretations of it might have value outside of this case. The naturalistic researcher does not maintain either, that knowledge gained from one context will have no relevance for other contexts or for the same context in another time frame (Erlandson et al. 1993, 32). Rather than attempting to select isolated variables that are equivalent across contexts, the naturalistic researcher attempts to describe in great detail the interrelationships and intricacies of the context being studied. Thus the result of the study is a description that will not be replicated anywhere. In a naturalistic study the obligation for demonstrating transferability belongs to those who would apply it to the receiving context. (Erlandson et al. 1993.)

In this study I have tried to describe the study “thick” enough to bring the reader vicariously into the context being described and to maximize the range of specific information that can be obtained from and about that context even that all this information is not used in this study. For the transferability of the study the remarkable issues both for the educational practises and theories of the views of science have been addressed.

**Dependability**

An inquiry must also provide its audience with evidence that if it were replicated with the same or similar respondents in the same
or similar context, its findings could be repeated. The inquiry must meet the criterion of consistency. Consistency is conceived in terms of dependability. To provide for a check on dependability, the researcher must make it possible for an external check to be conducted on the processes by which the study has been conducted. This is done by providing an “audit trail” that provides documentation and a running account of the process of the inquiry. (Erlandson et al. 1993, 33-34.) Taking into account of dependability the researcher must be consistent within the study and its methodological solutions and ensure that all the selections are justified in respect of the aims of the study and the role of the researcher is determined in the different phases.

Interpretations themselves are always contextualized and provisional. There is always the possibility of a new interpretation, in part because the context is always changing to include the previous interpretation as well as other developments (Wood and Kroger 2000, 165). The students’ ability to produce verbal data was good, but however their thoughts were sometimes difficult to gather. This makes demands on designing the instructions for writing and difficulties in questioning to achieve valid data. In this study instruction for the narratives was open because the aim of the data gathering has been to find out those things which were significant for the students. The students’ views were compared with many justifications, and interpretation was not based only on one justification. 399 descriptions were coded from the narratives. The ways used in this study, increased the dependability of the research results. Open instructions may have influenced on that even though a student had experienced science or science instruction significant, s/he did not write about it. It is possible that the students found some other things more essential to tell about. The students were asked to write one page, and this has possibly limited the data.

The collected data was not reviewed by the informants, because they had left the university at the time when the analysis was finished. The parallel analysis of the data was made for physics explanations in the phase of the pilot study to confirm the agreement of the two researchers and to avoid inconsistencies. Because of the similarities in the results of these two studies the parallel analysis was no more repeated in this study.
Confirmability

Objectivity is a goal of traditional research, but it is an illusion. The naturalistic paradigm affirms the mutual influence that a researcher and respondents have on each other. Nor are the dangers of reactivity ignored. However, no formal methods can be allowed to separate the researcher from the human interaction that is at the heart of the research. The dangers of reactivity are great: the dangers of being insulated from relevant data are greater. (Erlandson et al. 1993, 15.) In this study the influence of the researcher was decreased by asking the students to write the story after the education. At this point there were no more bindings between the researcher and the students and their writings could no more influence their course marks. However, the next students during the following years influenced me during the analysis, interpretation and writing processes. Tacit knowledge which has increased by working with the students has influenced my interpretations and conclusions. I have tried to minimize this influence at every phase by considering through the study process where my conclusions were really raising up.

The audit trail that was established to ascertain dependability by looking at the processes that have been used in the study also enables an external reviewer to make judgments about the products of the study. An adequate trail should be left to enable the auditor to determine if the conclusions, interpretations, and recommendations can be traced to their sources and if they are supported by the inquiry (Erlandson et al. 1993, 35). The trustworthiness of the work can be determined by describing how the interpretations were produced; making visible what has been done, specifying how successive transformations have been accomplished, and making primary data available to other researchers. The validity of research results is based principally on the process of data analysis. The data analysis in this study is based on the written representations of students’ thoughts and understanding. The language was a core component of interpreting the students’ reality and making their thoughts explicit. Accordingly, my position as a researcher between the students’ representations and the theoretical understanding has became essential; the reality which this study produces was built up through these factors. For enhancing the data analysis process and the interpretations of the authentic data, the different issues of the study were discussed with colleagues from several scientific disciplines. Thus
the interpretations of the research findings include the viewpoints from education to economy and sciences.

Methodologically the study has not been complicated. However, the connection between the two parts has been difficult to conduct. The analysis of the narratives has been a multidimensional process and has demanded that I have gone back to original data several times to reconstruct the reality under analysis. After the data collection of this study a narrative account has been used to research learning (see Mulholland and Wallace 2003). In the study of Mulholland and Wallace students were also asked to write about issues of personal importance, closely related to the science education subject being studied. The students have been free to choose their own issues, however, the given suggestions included previous experiences of learning science, their developing understanding of the nature of science and science concepts, and the ways in which science might be taught in their classrooms in the future. Despite the narrative of Mulholland and Wallace narrative method had not been used in the previous studies. Thus the narratives are seen as a new method to study views of science and, as such methodologically as a powerful tool and strength of this study. A case study is a tool in which writing an own story of teaching will help to understand own beliefs and values about teaching and reveal motivation for becoming a teacher (Campoy 2005). A case study is a problem solving process and reflection is a critical stage in the process. Reflection has been done in this chapter as carefully as possible taking into account all the criteria essential in qualitative research.

Based on the arguments set out above, the analytical process has been multi-phase and my theoretical understanding has been under critical evaluation when the data has been analysed according to the research aims. Thus, I have constantly reviewed research literature to increase theoretical and methodological understanding and to delve closely into variations of the data analysis process. According to the qualitative research orientation in this study the result categories have been grounded in the data. The categories have been chosen based on the literature after the first phase of the analysis to describe the issues under research as good as possible. Notwithstanding, the main purpose has been to obtain the similarities of the data and to interpret those findings through the context and the theories within the research area. Thus theoretical issues have always been, when necessary, included
in the discussion of the study findings. These discussions related the study to the study field and consequently obtained evidence for the external validity and transferability. Thus the current study has been rooted into the research field of views of science.

7.2 The implications for the educational practise, teacher education and curriculum

This study concerns the Finnish primary school teacher education and the important implications are related firstly, to my own work at Science and Technology Education and secondly, to science education of the primary school teacher students in general. The findings and the conclusions of this study may also concern science education in the teacher education in different countries. Consequently, the suggestions should be taken into account in developing work for the science curriculum.

What have I learned from my students? Firstly, this study has indicated that our primary school teacher students are well-familiarized with the pedagogical framework of science education. Although, the students had different views of science and of science instruction, some of the views dominated and could be captured. Many students showed the modern view of science instruction in some sub region of science education. The modern view of science instruction has often been combined with the mention of inquiry as an essential learning method in science. Based on the findings in this educational process, it seems that there is no need to focus essentially more on pedagogy of science or on the inquiries as a desirable learning method. The level of approach used in the education seems to be near the suitable level. However, this study has shown that open inquiries especially have been less considered. Involvement in scientific inquiry can range from relatively brief classroom activities to lengthy projects in research laboratories. Scientific inquiry involves student-centred projects, with students actively engaged in inquiry processes, and meaning construction with teacher guidance in order to achieve meaningful understanding of scientifically accepted ideas targeted on the curriculum. Physics practises in Science and Technology Education have after this study been redesigned, starting from small closed inquiries and ending up
to open inquiry in which topics ‘snow’ or ‘water’ depending on the season are preferred. Students often comment the importance of not being wrong, and it is hard for me to find ways of accepting and working with students’ science ideas rather than correcting them. Students’ ideas are the basis for a constructivist referent for teaching and learning, the idea that all starting points are meaningful to the learner who holds them, and thus, need to be used by instructors, and developed appropriately. This is difficult to do in practice. I have found myself torn between wanting to support my students but, equally wanting the students to think about what I see as a scientific way. The assistance in the open inquiry is still problematic for me and I need to develop my ability to guide rather than to teach.

Secondly, this study has led to some thoughts about the ratio between the pedagogical knowledge and subject knowledge in the education. For establishing the learning environment in which the students’ multidimensional development is promoted, the purposes of teaching and the starting points of teaching need to be clarified. Based on these two aspects of teaching the teacher needs to use pedagogical and scientific knowledge. In addition, both of these knowledge areas must be in harmony with the knowledge of the students’ understanding. How the primary school teacher achieves scientific knowledge and adapts it for pedagogical situations has an essential role in primary science as also at the higher levels of the education. Thus depending on how well the “language” between the teacher and the students about the scientific phenomena is understood, the students’ science understanding process can be supported and guided. This kind of awareness should be a core issue in the teacher training. Even though that the need to increase essentially the subject knowledge courses in Science and Technology Education has not been found, there seems to be a need to focus subject instruction more towards the explanatory feature. Although it has been the aim in the physics course, the findings of this study show that the education has not supported enough students’ ability to find the essential concepts in the physics phenomena and to explain the phenomena. In focusing on the explanations it has to be taken care of that scientific knowledge is used to support the students’ ways to explain scientifically. The nature of the exam should also be considered carefully for measuring understanding rather than remembering.
Thirdly, the nature of science in Science and Technology Education has been found to show up in a smaller role for students than the nature of science instruction. Many science educators want to help students to better understand the nature of science and its products. One approach to improve science teachers’ conceptions of the nature of science is to see an understanding of the nature of science as a learning outcome that can be facilitated through science process skills instruction, science content coursework, and doing science (Akerson et al. 2000). Researchers who have adopted this implicit approach (e.g. Palmquist and Finley 1997) have used science process skills instruction and/or scientific inquiry activities or manipulated certain aspects of the learning environment. The second approach is explicit and researchers who have adopted this approach (e.g. Abd-El-Khalick and Lederman 2000) have used elements from history and philosophy of science and/or instruction geared toward the various aspects of the nature of science to improve science teachers’ conceptions. The idea of making the nature of science explicit throughout the science education is supported also by Moss (2001). To him understanding the relationship between explicit instruction and implicit messages of the nature of science is critical if we are to teach effectively the nature of science. Explicit and guided attention to and reflection on the nature of science in the context of the authentic scientific research experiences influence the views of the nature of science (Schwartz et al. 2004). Reflection is a metacognitive activity and can serve to inform the learner of her/his developments in concept understanding and to lead to deeper understanding.

More promising ways of changing teachers’ inauthentic views of science could be more direct discussion about the philosophy and history of science. This investigation supports the intuitive assumption that students will learn about science simply by doing science contrary to the results of the work of Bell et al. (2003). The results of Bell et al. have emphasized the importance of epistemic demand and systemic reflection upon one’s actions. Doing is not enough, thinking must be included, as they have stated. In this respect, however, this study agrees with them. Doing science is insufficient for a student in order to develop conceptions of the nature of science. Primary school teachers are not teaching about science, not “doing” science. To teach science, one must have knowledge of the concepts and effective approaches
to teaching science. As such, to teach about the nature of science and inquiry, the teacher needs knowledge of the nature of science and inquiry, and pedagogical knowledge for them both. We should have limited aims in introducing questions concerning epistemology and the nature of science in the classroom. A more complex understanding of science is needed, but not a total or even a very complex understanding (Matthews 1998). Philosophy is not far below the surface in any science classroom. Although the nature of science has been included implicitly in the education under consideration, it does not seem to be enough. Explicit approaches are also needed. It is unrealistic to expect students or prospective teachers to become competent historians, sociologists, or philosophers of science. However, in addition to their experiences with school science, teacher candidates mainly learn science content in traditional courses offered by various disciplinary departments. When students enter teacher education program with naïve views of the scientific enterprise, science educators need to continue their efforts to develop and assess the effectiveness of various instructional approaches aimed at promoting science teachers’ views of the nature of science in the context of education courses, particularly science methods courses, in which they come in contact with prospective teachers. In this regard, it cannot be overemphasized that it is recognized that science methods courses might not be the optimal context for developing science teachers’ nature of science views. However, in many cases, they are the only available context. (Akerson et al. 2000.) Pre-service and novice teachers consistently demand one-to-one correspondence between the content of education courses and anticipated actual teaching content/settings. Such demand is also evident in the case of preservice teachers and nature of science instruction (Abd-El-Khalick et al. 1998). Developing science teachers’ views of the nature of science would be achieved best in the context of science content courses approach (Akerson 2000). An explicit, reflective approach to the nature of science instruction embedded in the context of learning science content would not only facilitate developing science teachers’ nature of science views, but might go a long way in helping teachers translate their nature of science understandings into actual classroom practices.

It has been decided to include the nature of science more explicitly inside Science and Technology Education courses at the Department
of Applied Education to change students’ old fashioned views. The suitable forum would be the first course of the entity in which the issue is discussed in the lectures although it is science method course rather than science content course. Also teaching material has been developed by writing teaching handouts for the subject courses: biology, chemistry, physics and geography, which the subject departments carry out. In these handouts the nature of science is shown in the stories of scientist, scientific inquiry and its products. In this case the nature of science is connected to the science contents education. Through the stories, the underlying conceptual chemistry was presented also in the study of Tao (2003) in a context that gives it depth of meaning and coherence. This, it is argued, is much more effective than presenting the same concepts in the traditional abstract, context-free ways which many students find difficult. The science stories had in his study considerable impact on students, but they could lead to adequate as well as inadequate views of the nature of science. We also believe that stories will help students to achieve the understanding of the different aspects of science being considered both in science method as also in science content courses.

Fourthly, based on the findings of this study process, it seems that except that more effort should be paid on the situations in which the students come across the nature of scientific knowledge and science itself, they should also come across the relations between science and society as also between science and technology, and across sustainable development. This study advocates Science and Technology Education, and its advantages rely on the ways in which education promotes the teacher students skills to a larger extent and fulfils the demands set by human constructivist science educators. This study suggests STS approach for use in teacher education science for improving knowledge of the relations between science, technology and society. On the other hand the STS approach offers a fruitful context for students to learn inclusion for their future profession.

This study has had some concrete influences on the curriculum of the Science and Technology Education. The students told little in their narratives about societal aspects of science and sustainable development. They paid little attention also to the technology in the context of industry. Thus, the curriculum has been changed to include lectures on these issues. The students’ projects have later pointed more to the societal factors in STS education. For example,
The Sun already rose high and the days were long when I finished the corrections of the draft.

*Alles, was uns fesselt und beschäftigt, hat nur einen bedingten Wert. In einem Augenblick, in der nächsten Stunde kann es vollständig wertlos werden.*

Albert Schweitzer


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Master thesis

Appendix

Fysiikan hahmottamista ja osaamista koskeva kysely.
Kevät 2000/TK/tokla

Nimi

Koulutuslaji

Vaosikurssi

Olen opiskellut lukiossa fysiikkaa ______ kursin/kursseja.

OSIO 1

FYSIKKAISEN TIEDON HAHMOTTAMISTA KUVAAVAT TEHTÄVÄT

Valitse mielestäsi oikea vaihtoehto ympyrärimällä se ja perustele valintasi. On nimenomaan tärkeää, että perusteet valintasi muistotulostuksissa olevat.

1. Miksi Maata kiertävissä satelliitteissa oleva astronautti on painoton?
   a) Maan vetovoima ei enää vaikuta hänelle,
   b) Maan ja Kuun vetovoimat kumoavat toisensa,
   c) Maan ja Aurinkon vetovoimat kumoavat toisensa,
   d) Astronautti ei olekaan painoton.
   Perustelu:

2. Kunnossa on edukkaampaa punnita itsensä, meren rannalla tai vuoristossa, jos haluaa painottaa olevan mahdollisimman pienin:
   a) meren rannalla,
   b) vuoristossa,
   c) ei valit.
   Perustelu:

3. Auto ajaa sadan kilometrin matkan Helsingistä Hämeenlinnaan. Ensimmäiset 50 kilometriä nopeus on ruuhkien vuoksi 40 km/h. Millä nopeudella olisi ajettava loppumatka, jotta keskinopeudeksi tulisi 80 km/h?
   a) 120 km/h,
   b) 160 km/h,
   c) 200 km/h,
   d) ei ole lainkaan mahdollista.
   Perustelu:
4. Miten kiiy huoneen lämpötilan, kun jääkaapin ovi avataan?
   a) Lämpötila huoneessa ei muutu,
   b) huone lämpenee kokon ajan,
   c) huone jäähtyy kokon ajan,
   d) uhkisi huone lämpenee, sitten jäähtyy,
   e) uhkisi huone jäähtyy, sitten lämpenee.

Perustelu:

5. Keittötäessä kannullinen tee vettä nopein tapa on käänää liesi heti suurimmalle mahdolliselle teholleen. Mutta mikä on edallisin tapa?
   a) käännetään liesi hiljaisimmalle teholle, jolla vesi juuri ja juuri alkaa kiehua,
   b) käännetään liesi suurimmalle teholleen,
   c) keittötavalla ei ole vaikutusta sähkön kokonaiskulutukseen.

Perustelu:

6. Täysin tyvenen veden pinnasta heijastunut maisema on alkuperäistä hieman tummempi ja ylösalaisin käännyt. Onko se muuten samanlainen?
   a) on,
   b) ei.

Perustelu:

7. Minkä värinen on Auringon runeen heittämä varjo?
   a) musta,
   b) harmaa,
   c) punainen,
   d) sininen.

Perustelu:
8. Autoradion antennin päissä on nuppi, koska
   a) se parantaa kualuuvuutta,
   b) terävä kärki olisi vaarallinen,
   c) se estää antennin värinään ajoijmassa.

Perustelu:

9. Suunnistajat tiedät, ettei voimalinjojen alla kompassin voi luottaa. Jos sähkölinja kulkue
   kuvan osoittamalla tavalla itä-länsisuunnassa, niin linjojen alla kompassin neula osoittaa
   a) pohjoiseen,
   b) etelään,
   c) itään,
   d) länteen,
   e) minne tahansa.

Perustelu:

OSIO 2

**FYSIIKAN TIETOA TESTAAVAT KYSYMYKSET**

Vältte mielestäsi eikä voi huoltaa jokaisesta vastauksesta ympyräpalilla se.

1. Nopeuden yksikkö SI-järjestelmässä on
   a) km/h
   b) km/s
   c) m/s.

2. Turkka digitaalivaaka näytti Pekan massaksi 64,145 kg. Pekan on järkevää ilmoittaa
   massaksi
   a) 64 kg
   b) 64,1 kg
   c) 60 kg.

3. Luvussa $10^9$ on neljä
   a) yhdeksän
   b) kymmenen
   c) yksitoista.

4. Liike on tasaisa liiketta, jos
   a) nopeus on vakio
   b) aika on vakio
   c) matka on vakio.

5. Voima on
   a) massa ja ajan tulo
   b) massan ja kihtyvyyden tulo
   c) massan ja nopeuden tulo.
   d)

6. Pekan (massa 60 kg) paino Maan pinnalla on noin a) 60 N  b) 600 N  c) 6000 N.
7. Potentialienergialla tarkoitetaan
   a) potentialista mahdollisuutta saada energiaa
   b) liikkoessä olevan kappaleen energiata
   c) energiata, joka kappaleella on asemansa perusteella.

8. Liike-energialla tarkoitetaan
   a) liikkuvan kappaleen energiata
   b) pysähtyneen kappaleen energiata
   c) kumpaakin edellistä.

9. Jos ajonopeus kolminkertaistuu, niin jarrutusmatka
   a) pysyy samana
   b) kolminkertaistuu
   c) tulee yhdeksänkertaiseksi.

10. Tasopeeliin muodostama kuva on a) todellinen kuva b) virheellinen kuva c) valekuva.

11. Hyvin kaukaisesta esineestä (äärettömyydestä) saapunut valo muodostaa kuvan kuperan linssin
    a) eteen b) taakse kahden polttovälin etäisyydelle
    c) taakse yhden polttovälin etäisyydelle linssistä.

12. Interferenssitä tarkoitetaan aaltoliikkeen
    a) heijastumista b) yhteisvaikutusta c) aaltojen nopeutta.

13. Diffractionslla tarkoitetaan aaltoliikkeen
    a) heijastumista b) taipumista c) taattamista.

14. Valo on a) pitkäistä b) poikittaisa.c) sekä pitkäistä että poikittaisa aaltoliiketta.

15. Spektori on
    a) osa sähkömagneettista säteilyä
    b) sähkömagneettisen säteilyn intensiteetijakauma aallonpituuden suhteen
    c) näkyvän valon aallonpituusjakauma.

OSIO 3

METAFORA: Kirjoita mieleesi tuleva metafora eli kielikuva seuraaville asioille.

1. Tekniikka

2. Fysikkka

3. Luonontieteet

4. Kemia

Kiitos vastauksistasi!