The development of an Internet-based learning environment to support physics teaching/learning outdoors

Oleg Popov and Rolf Engh

Department of Mathematics, Technology and Science Education, Umeå University

Abstract

The overall aim of this project was to contribute to making the study of physics in teacher education more effective, interesting and more attractive to women student, by developing an activity- and inquiry-based outdoor education approach supported by a web portal http://outdoorphysics.educ.umu.se/. The website has a two-fold function in the project. On the one hand, it is a mediating tool for learning physics, containing suggestions of cases for outdoor activities and interactive computer models and visualisations supporting the understanding of physics. On the other hand, it presents a cumulative result of the project development, containing students' and teachers' work, ideas and recommendations. It has been developed in the form of a multilingual didactic material so that it can also be used in master courses for international students. This report covers a one-year project supported by the Swedish Council for the Renewal of Higher Education.

Keywords:
”Outdoor Education”, ”Physics Instruction”, ”Computer Assisted Learning”, “Pre-service Teacher Education”, “Higher Education”, “Instructional Innovation”

Introduction

Physics is considered to be a difficult subject, demanding much effort. Our previous research (Popov, Zackrisson and Olofsson, 2000) shows that many students perceive physics mainly as applied mathematics with a limited connection to everyday life. Physics is also associated with memorising formulae for problem solving and working with a range of laboratory equipment. The students have problems in seeing connections between models of physical phenomena described by formulas, and their own experiences of reality. This happens usually because students are not used to constructing physics models themselves. They therefore cannot connect these models to reality.

Riess (2000) summarises the results of some recent survey studies in Germany as follows: “Science (except biology) and mathematics are the most unpopular subjects in German schools, where physics is disliked most. The rejection by girls and young women is particularly high.”

Decreasing motivation and competence in physics studies among students at different educational levels has been an issue broadly discussed by researchers and by politicians (e.g. Sjöberg, 2001, OECD, 2005). Developing science courses, in particular in physics, which are more attractive to students and improve the quality of learning outcomes, is a challenge that faces teacher educators in all countries.

In science teacher education courses in Umeå, we broadly use physics activities and examples from the nearby environment. Activities in nature are popular among the student teachers. In Sweden, we have a unique advantage in having lawful access to the countryside granted by the “Allemansrätten” (literally: everyman’s right). This is a unique Swedish tradition that gives every person free access to nature regardless of land ownership. One consequence of this is that in many Swedish schools, outdoor education is an important curriculum component (see e.g. http://www.naturskola.a.se/). The advantages of using outdoor pedagogy for educational purposes are broadly presented in Swedish academic literature (e. g. Brugge, B., Glantz, M., Sandell, K., 2002, Dahlgren, & Szczepanski, 1997, Ericsson, 2002, Palmberg, I., Palmberg, S., 2002, Sellgren, 2003)

Different kinds of excursions and activities in natural surroundings are popular – however they seldom include physics topics. Teachers appear to have particular difficulties in organising the study of physics in outdoor settings. This fact is also confirmed by research presented in thesis of our students (Forsgren, Johansson, 2004).

This project arose from the need to systematise the results of the students’ activities during our science education courses and also provide them with a place to find inspiration for their future work in schools. Therefore, we aimed to reinforce outdoor learning activities with an Internet-based learning environment that includes the best examples of students’ work, computer visualisations and modelling of outdoor activities and pedagogical content knowledge for outdoor physics.

Our work is related to other educational projects in Sweden, for example, the use of playgrounds and amusement parks in school and university physics courses (Gothenburg/Prof Pendrill), environmental physics (Malmö/Ass. Prof. Areskoug), outdoor pedagogy (Norköping/Ass. Prof. Szczepanski) and adventure education (Luleå/Ass. Prof Furmark), as well as some projects in Germany, USA, Ireland, Cyprus and Russia. We have well-established contacts with researchers in these countries.

Thus, based on these experiences, the ‘outdoor physics approach’ was developed in this project and presented on the website http://outdoorphysics.educ.umu.se with support from the Swedish Council for the Renewal of Higher Education.

The original goals of the project were defined as ‘to make the study of physics in teacher education more effective, interesting and “female-friendly” by developing activity-based outdoor education modules supported by an Internet-based learning environment. An interactive website for outdoor physics will be created and piloted in different science courses’.

Theoretical framework

The Cultural-Historical Activity Theory (CHAT) is used as a theoretical ground and methodological framework for the project. CHAT belongs to a family of socio-cultural theories originated from the works of Vygotsky and his research fellows in the early 20th century.

CHAT underlines the centrality of cultural and social contexts in human development. The context-relatedness of learning is central in Vygotsky’s theory. We decided, following this line of thought, to place some studies of physics (i.e. laws and properties of nature) directly in natural settings. Any natural context that is easily accessible to students today has strong cultural and social dimensions. We assume that new context will create new opportunities for learning.

Departing from Vygotsky’s ideas, Leont’ev (1981) built up a foundation for a theoretical description of human psychological development and behaviour based on the study of human activity. According to Leont'ev (1981), the first and most fundamental form of human activity is external, practical activity. Thus, we designed a pedagogical approach based on meaningful practical activities outdoors.

The fundamental claim of the CHAT is that human activity (on both the interpsychological and the intrapsychological plane) can be understood only if we take into consideration technical and psychological tools that mediate this activity. In outdoor physics, investigation techniques or processes of science are artefacts that have particular significance. These mental and manipulative skills serve as important tools in the culture of science and in our project. The large-scale physical artefacts (like cable drums, cars, barrels, etc) have also been used as tools for stimulating learning. We have departed from the hypothesis that “size does matter” when students’ have the possibility to explore physical phenomena outside of the classroom walls. For example, in studying torque there is a 'traditional' physics experiment with a spool. If the line leaves the spool from the bottom of the axle, and is gently pulled, will the spool move forwards or backwards? We adapted this experiment to the outdoors environment using a rope and a cable drum, see Fig 1 below.

Fig 1. Changing scale of the experiment outdoors

According to Leont’ev (1981), activities are object-related. The content of human activity is determined first of all by its object. The object of activity is always a value-loaded social object, i.e. a human-nature or human-technology system. When doing outdoor physics, objects of learning activities are material objects (natural or human made) with their properties reflected in scientific principles, laws, and theories of physics. Thus, the content of learning was the acquisition of knowledge (embodied in learning objects) about properties and laws of nature. For example, when making a construction of a hot-air balloon the content of learning was about understanding density, heat transfer and Archimedes law.

CHAT is based on an understanding of activity as a constantly developing and complex dynamical process. Leont'ev often referred to constant transfers within the system "subject – activity – object" (Stetsenko, 2005). The primary distinguishing characteristic of the learning activity in general is that its main expected outcome is not only object transformation, but also the development of the subject of the activity (the learner). This means that such an activity has to result in the learner's personal development. In an outdoor physics approach, experiences with cognitive and physical tools, instruments and artefacts (like building a water rocket and exploring its properties, doing experiments and measurements with the help of binoculars) are valuable for the development of the learner's scientific worldview and his or her skills in and attitudes towards science.

Embodied knowledge

Teaching in traditional educational settings often neglects the knowledge that we possess through bodily contact with the world, but this is a constituent part of our worldview. Our learning about nature is also shaped by this way of knowing. As Bonnett (2004, p. 98) suggests, 'In our bodily intercourse with the world the abstract idea plays a less dominant role, we engage with the world less through an ordering cognition and more through a responsive *sensing*, as say when we feel the quality of the resilience of this piece of grass underfoot or the quality of resistance of a particular piece of wood to the chisel."

Learning about physical phenomena and the properties of the surrounding objects can be assisted by direct bodily contact with them. Feeling the air-resistance force through the open car window gives 'first hand' experience and facilitates understanding of the physical properties of the air. We assume that if carefully used, embodied knowledge can be a complement to facilitate an understanding of physics.

Teaching science as inquiry

Teaching science as inquiry was the main curriculum standpoint of the project. In general, inquiry refers to the work that scientists do when studying the natural world i.e. posing questions, gathering evidence and constructing explanations of natural phenomena. According to Tanner and Tanner (1990, p. 280), scientific inquiry is 'the method of gaining knowledge and transforming it into working power'. Acquired work methodology and knowledge build a base for development of individuals' analytical thinking and skills of investigation. Inquiry-based instructional strategies lead to learners' more autonomous problem-solving capacities and thus to 'freedom from depending on the teacher' (Tanner, Tanner, 1990, p. 275).

The OECD (2003) suggests the importance of learning in school science classes about general methodological principles of scientific activity (inquiry), such as:

- Recognizing scientifically investigable questions
- identifying the evidence needed in a scientific investigation
- drawing up or evaluating conclusions
- communicating valid conclusions
- demonstrating an understanding of scientific concepts

Therefore, we assume that prospective teachers should acquire competence in these skills.

Science studies in general and physics in particular are subjects based on practical activities. According to the modern vision of practical/laboratory experiences learning goals for such activities could be formulated as follows:

- Mastery of subject matter

- developing scientific reasoning
- understanding the complexity and ambiguity of empirical work
- developing practical skills
- understanding the nature of science
- cultivating interest in science and interest in learning science
- developing teamwork abilities (National Research Council, 2005)

Traditionally, these goals are to be achieved in a laboratory or classroom learning environment. Yet we suggest that physics teaching/learning placed in natural settings can bring a number of pedagogical advantages. First of all, most of the outdoor activities naturally demand a more open inquiry approach to work, in identifying and formulating the problems, planning and drawing up experiments. In addition, in studying real objects and phenomena the students must learn to select the key factors, evaluate other relevant parameters and carry out the appropriate design of activities. Most of the outdoor activities naturally demand teamwork, as it is simply impossible to do them individually. Addressing these issues is especially important in science teacher education.

Gender perspectives

Low enrolment and performance of girls in science courses are issues of concern in many countries (OECD, 2005). In almost all Western European countries, systematic efforts have been made to encourage girls to choose science as a school subject and to continue their study of science at higher education levels. Sweden has a high level of gender equity in society and in education in general, but experiences a similarly clear gendered profile of interests for studying physical sciences and careers patterns as in other developed countries (OECD, 2005).

Different explanations have been put forward as to why gender differences exist in achievement, experience, interest and attitude concerning the study of the natural sciences, given that girls tend to be over-represented in most other academic subjects. It seems clear that the way gender is socially constructed (Connell, 1987) influences students' interests in, and attitudes to science.

Active discussions have taken place on how to make science more attractive to female students through, for example, the use of themes and problems of relevance to their daily lives (Öhrn, 2002). Female students appreciate and prefer to discuss the aesthetic aspects and ethical values of science content. Meanwhile, both sexes are interested in ICT and outdoors activities. At Umeå University, almost half of the examination papers in teacher education during the last five years related to outdoor activities were written by female students. However, as the research of our students in schools show, girls have less positive expectations about outdoor physics than boys. Therefore, it has been a challenge for us how to make selection, organisation and presentation of outdoor physics activities attractive for female students.

We agree with Svennbeck (2003) who argues that the perception of and relation to nature is gender specific and therefore it is important both how and where the physical sciences education is carried out. The role of teacher education is crucial in making science education more gender inclusive. Our outdoor courses are dominated by female students. We now also have students writing their thesis on gender perspective in outdoor education. This issue is of priority in our department.

Methods

The development of pedagogical approaches and cases for the study of physics in the outdoors in teacher education included:

1) The collaborative development of new activities and/or adjustment of existing cases of activities to different educational levels and making them more gender sensitive.

2) The presentation of our students' physics outdoors activities conducted in schools and teacher education on the web based archive.

3) Modelling/visualising outdoors activities using Power Point, Flash, Java or similar programs.

4) The conceptualisation and theoretical development of the outdoor physics approach.

5) The publishing of theory, literature, links and other relevant recourses on the web (in our multilingual website).

The methodological foundation of the "outdoor physics project" was our commitment to hands-on inquiry-based learning. Other important issues were extending the learning environment to outdoors and augmenting it with use of ICT tools.

Many of our students are interested in outdoor pedagogy but they lack knowledge of how to teach physics content in the open air. We had anecdotal evidence that the situation is quite similar in most of the schools in Sweden where teachers declare interest but lack competence in this form of teaching (Forsgren, Johansson, 2004; Markström, Cedergren, 2005). Therefore, it was important to help our students and teachers in schools to deal with teaching physics outside the classroom.

Currently, at Umeå University, prospective teachers can choose to do physics activities outdoors in different forms and occasions, such as:

- Doing course assignments during the general undergraduate science courses.
- Developing and trying out 'cases' with pupils during their school practice.
- Carrying out outdoor science experience can be a part of minor research activities during diploma/examination work and master course assignments.

On these occasions (several times per term), students are assisted and supervised in their work by the project members.

Different methods of conducting outdoor activities are used:

- Play and learn in the open air (PLOA).
- Predict – observe – control – explain (POCE).
- Prove through action and construction (PAC).
- Explore Authentic Problems (EAP).

The students were actively involved in the development of the website. They were also working practically with development and checking of the viability of outdoor teaching examples – cases. Some of them carried out the pilot studies with cases in their course and examination work. On several occasions, cases were tried out during the students' teaching practice in schools. Student teachers have also studied pupils' and teachers' attitudes towards science activities outdoors (Forsgren, Johansson, 2004; Markström, Cedergren, 2005). The feedback from the students on the context, process of development and results of their field work were studied by the teacher trainers involved in the project in order to find ways of incorporating such approaches into existing curricula in schools and teacher training.

Project activities and results

Selection of the outdoor physics cases

The work on development of the general principles for selecting cases for outdoor activities was intertwined with the practical testing of the concrete cases and the web-site development.

The following criteria became apparent in this process:

Relevance to the socio-cultural and natural context. The familiar natural environment and everyday life context of the cases are considered as important factors.

A practical exploratory activity should be involved in each case. Preference should be given to cases where experiments can only be done outdoors (exercises like launching a water rocket, counting snowflakes, making explosions, etc.), or where practical activities can be naturally done outdoors (like measuring the speed of water flow in a river, or finding 'temperature changes' in the soil with depth during the day).

Preference given to cases encouraging exploration of open-ended authentic problems. Dealing with natural objects and phenomena, students should have the possibility to formulate their own study problems or concretise suggested ones. The results of the inquiry can generate additional questions, research issues and problems and give an impulse for further investigations and corrections.

Cases should be attractive for students. The formulation of problems should call for students' curiosity.

Cases are organized on three levels of difficulty:

Initial level: Based on students' practical experience of dealing with everyday problems without preliminary physics knowledge.

Medium level: Conceptual physics with or without very simple formulae like $v = s / t$.

High level: Activities are more advanced and complex. Calculations are often required. Cases are based on creative problem solving.

These criteria were formed gradually during the project work and they can be evolved further.

Examples of cases

A variety of outdoor activities were developed and tested by our students. Some examples of outdoor physics cases are presented below. (To see other examples/cases go to the project website http://outdoorphysics.educ.umu.se.)

Lift a car

A prospective teacher is exploring 'lever principle' with his class during his school practice (Forsgren, Johansson, 2004). The grade 7 students are faced with the task of finding a way to lift the teacher's car 'to change a flat tire' without using a jack.

Fig. 2 Lifting the teacher's car with help of a lever

This is an example of a case at the initial level of difficulty.

Studying the flying capacity of a water-rocket

Launching a water-rocket is probably one of the most popular science exercises conducted outdoors in schools around the world. Construction tips and design suggestions for different types of water-rockets you can find on the Internet (see for example Water rocket index for teachers and students). Google gives about ninety thousand hits for 'water rocket'.

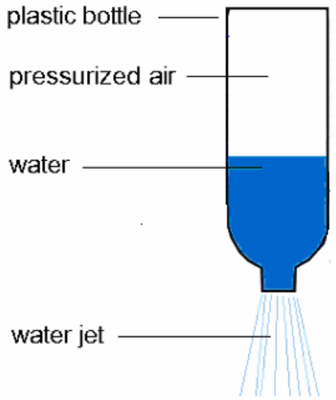

Fig. 3 Schematic picture of the water-rocket construction

Students are challenged to change different parameters in launching a rocket (like proportion of water and air in the bottle) and observe how they influence the rocket's flying capacity. This is another example of a case at the initial level of difficulty.

For other examples see the website: http://outdoorphysics.educ.umu.se.

The multilingual website

Designing and constructing the website (http://outdoorphysics.educ.umu.se) as a bank of cases and a database for the students' work activities has been another priority of the project. The website is oriented to teacher educators, school teachers, and prospective science teachers.

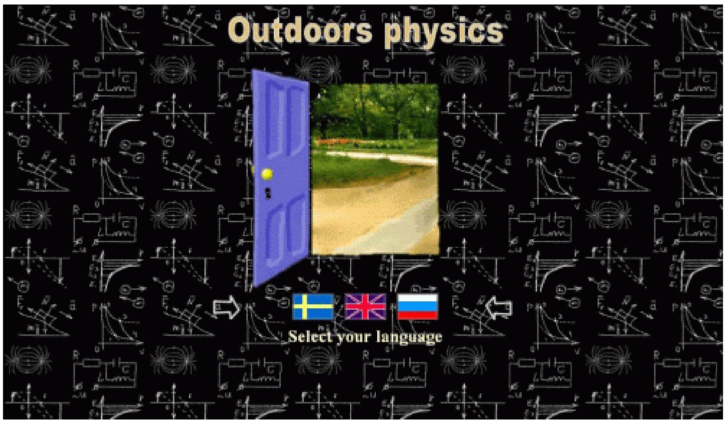

Fig.4 Entrance to the multilingual ‘outdoor physics’ website

The learning tasks presented on the website (the cases) are organized with respect to the level of difficulty, field of physics and natural objects used in the activity. About fifty cases are currently (April 2006) presented on the Swedish and the English versions of the website.

The structure of the website is presented in Figure 5.

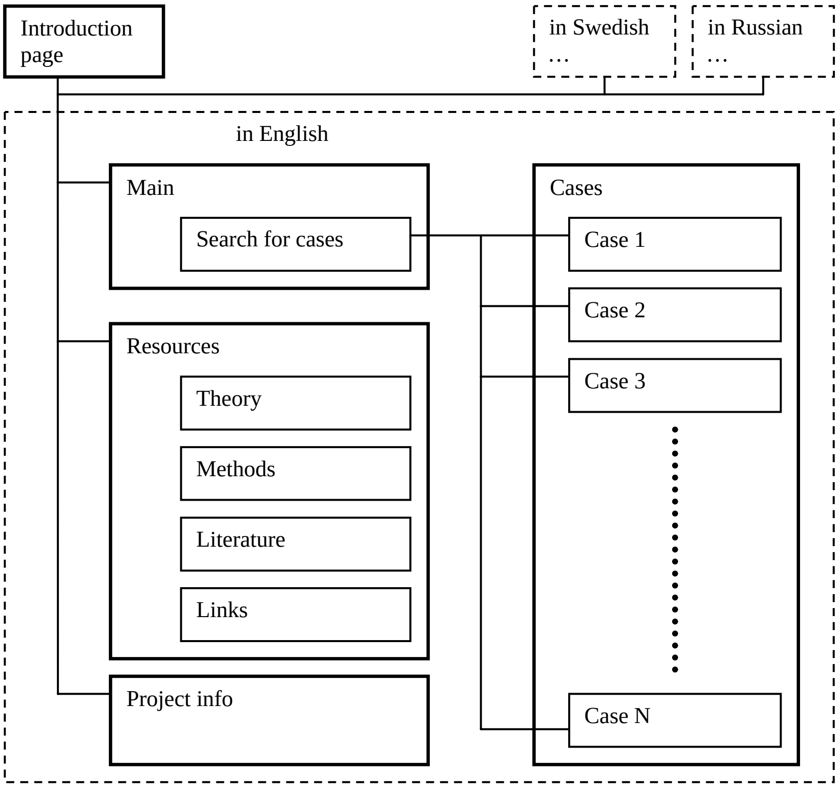

Fig. 5 The structure of the website

We have attempted to present each case as an open authentic problem with various possible solutions and usually only a few hints are given for conducting the practical activity or explaining the results. Hyperlinks are provided giving examples of other similar activities available on the Internet or students’ practical work in schools or courses with more detailed descriptions of activities in working with the cases.

Some cases are supported by interactive computer models (ICM) that can be used to inspire inquiry, and for illustration and analysis of observed phenomena in order to make physics more explicit and understandable.

Conclusions and perspectives

This report presents an account of a one-year project supported by the Swedish Council for the Renewal of Higher Education. The focus of our work during this year was on developing theory and methodology for an outdoor physics approach, the testing of cases and designing and constructing the website. We have also started pilot activities on the use of handheld computers for data collection in outdoor settings.

In general, the students' and teachers' evaluations of these teaching methods showed appreciation of the activities and satisfaction with the approach. However, we have not had the possibility within the one-year framework to do systematic research on the implementation and evaluation of the approach. This is our plan for the near future. We face a challenge in the development of new methods of assessment and control of the quality of activities. The outdoor approach has a clear practical orientation and naturally demands systematic formative assessment.

Support from the Swedish Council for the Renewal of Higher Education gave us the necessary momentum for further development of the outdoor physics approach as a part of our ordinary activities in science teacher education. We can state that this is a work in progress. New teachers and students are getting involved in the project. Recently, Christofer Larson and Mattias Eriksson finished the development of a pilot version of an administrative interface for handheld computers to be used for "science trails" outdoors. This was their D-thesis work. A course for Summer University named "Exploration of science in the Northern Landscapes" based on the outdoor physics project and oriented towards international students is under preparation.

This approach seems to be appropriate for creating new learning opportunities for students with special needs (e.g. with physical impairments) or students from socially disadvantaged groups. We have started preparatory work in this direction in collaboration with Umeå municipality.

Some European colleagues have become interested in our work, so we have successfully applied for the European project called OutLab – "Outdoor Laboratory for Innovative Science Teacher Education".

Cooperation in this area continues with the Pedagogical University in the twin city of Umeå – Petrozavodsk – in the North-Western Russia, where the outdoor approach is integrated in the faculty of physics and mathematics' introductory physics course.

In summary, the teacher trainers involved in the project could see evidence that inquiry based outdoor teaching can raise the level of interest and motivation among students in studying physics. Prospective teachers have through the project gained the possibility to acquire more confidence to teach physics in an innovative way, which is needed in schools. This gives us the inspiration to develop the approach further.

References

Bonnett, M. (2004). *Retrieving Nature: Education for a Post-Humanist Age*. Blackwell Publishing.

Brugge, B., Glantz, M., Sandell, K. (2002). *Friluftslivets pedagogik.* Stockholm: Liber.

Connell, R. (1987). Gender and Power. Society, the Person and Sexual Politics. Cambridge: Polity Press.

Dahlgren, L & Szczepanski, A. (1997). *Utomhuspedagogik. Boklig, Bildning och sinnlig erfarenhet.* Linköping: Linköpings Universitet, Skapande Vetande.

Ericsson, G. (2002). *Lära ute.* Frilufsfrämjandet.

Forsgren, T., Johansson, R. (2004) *Fysikundervisning utomhus*. Unpublished undergraduate theses. MaTNv inst . Umeå University.

Leont'ev, A.N. (1981). *The problem of activity in psychology*., in J.Wertsch (ed.) The concept of Activity in Soviet Psychology. (pp.7-71), NY, M.E.Sharpe Inc.

Markström, P., Cedergren, A. (2005). Praktisk fysik i grundskolans tidigare år. Unpublished undergraduate theses. MaTNv inst . Umeå University.

National Research Council (2005). *America's lab report*. Washington, DC: National Academy Press.

National Research Council (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press.

OECD (2003). *Scientific Literacy*. In The PISA 2003 Assessment Framework – Mathematics, Reading, Science and Problem Solving Knowledge and Sills. Accessed on the Internet at http://www.pisa.oecd.org/dataoecd/38/29/33707226.pdf 16 April 2006.

OECD (2005). OECD Global Science Forum. *Activity on Declining Interest in Science Studies Among Young People*. http://www.caos.nl/ocw/doc/Preliminary_Findings2.pdf .Conference on 'Declining student enrolment in science and technology' in Amsterdam on Monday 13-15 November 2005. Accessed on 26 April 2006. http://www.caos.nl/ocw/programme.html

Palmberg, I., Palmberg, S. (2002). *Vinter och vår i uteundervisning.* Åbo: Pedagogiska fakulteten.

Popov, O., Zackrisson, I., Olofsson, K-U. (2000). *How student teachers 'think physics*'. A case study of three groups of primary student teachers with science specialism. Paper presented at international conference: Physics Teacher Education Beyond 2000, Barcelona, August 27-September 1, 2000.

Riess, K. (2000). *Problems with German Science Education*. Science and Education, 9, pp. 327-331.

Sellgren, G. (2003). *Naturpedagogik*. Ekelunds Förlag AB.

Sjøberg S. (2001). *Science and Technology in Education – Current Challenges and Possible Solutions*: http://www.eu2001.se/education/eng/docs/uppsala_discussion_sjoberg.pdf Accessed on 26 April 2006.

Stetsenko, A. (2005). *Activity as Object-Related: Resolving the Dichotomy of Individual and Collective Planes of Activity*. MIND, CULTURE, AND ACTIVITY, 12(1), 70–88.

Svennbeck, M. (2003). *Omsorg om naturen : Om NO-utbildningens selektiva traditioner med fokus på miljöfostran och genus.* Uppsala: Acta Universitatis Upsaliensis.

Tanner, D., Tanner, L. (1990). *History of the school curriculum*. Macmillan Publishing Company. New York.

Öhrn, E. (2002). *Könsmönster i förändring? En kunskapsöversikt om unga i skolan*. Stockholm. Skolverket.