# Enhancing Primary School Student Teachers' Perceived Physics Related Self-Efficacy

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## Introduction

This paper describes the novel course called physics didactics in the primary school teacher education programme at the University of Helsinki. By *didactics*, we mean the field of educational science: theory and practice of teaching and learning as understood in Germany and Scandinavia by the term *didaktik*.

The National Core Curriculum for Basic Education (NCCBE, 2004), introduced by the Finnish National Board of Education, has for the first time described specific goals and contents for the novel subject *physics and chemistry* for grades 5 and 6 (pupils aged 11-13). This poses a challenge for pre-service teacher education to which we need to respond. At the University of Helsinki, we have reformed our class teacher education programme within the framework of the Bologna process taking into consideration the national curricular renewal in basic education.

In Finland, there is no national curriculum for teacher education; each university by itself decides how to organise the teacher education programme. The government lays down regulations only for the guidelines on the structure of the programme. Figure 1 presents the structure of the primary school teacher education programme. Primary school student teachers study the master's level degree, with education (or educational psychology) as a main subject including the master's thesis with research methodology, and school practice. The minor subject could be for example mathematics, offering a qualification to be a mathematics teacher in lower secondary school. The minor subject could also be a combination of university studies depending on a student teacher's interest. Student teachers have to study multidisciplinary studies that focus on subject knowledge and subject didactics. The extent of the course described in the paper is three ECTS credits.

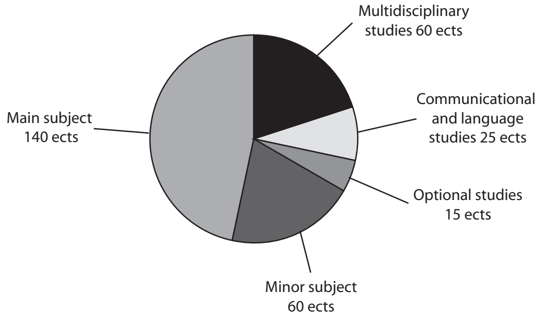

***Figure 1. The primary school teacher education programme at the University of Helsinki. 'Multidisciplinary studies' includes the physics didactics course.***

Objectives for the physics didactics course can be divided into two categories: subject knowledge and knowledge of physics teaching and learning. For the former, the objectives are that student teachers understand physics models at the qualitative level (for example Newtonian basic laws as models to explain changes in motion), have skills for practical work, and have knowledge about the nature of physics. For the latter, the objectives are that student teachers learn knowledge concerning pupils' ideas of physics, appropriate teaching methods, models for conceptual change, and so forth.

However, the course design is not an easy task. The students who apply for class teacher education are typically oriented more towards arts than towards science. In Finnish upper secondary school, students have considerable freedom to choose subjects. One introductory course on physics is compulsory for all. However, a number of students who start studies in the class teacher education programme came from arts-oriented schools where all science subjects are totally voluntary. Thus, student teachers who participate in the physics didactics course typically have very limited physics literacy.

Thus, they are insecure with regard to subject knowledge.

The challenge of designing the course is that in the relatively short period (10 hours of lecturing, 8 hours of group activities in the laboratory, and 60 hours of independent work) student teachers should study the contents of school physics as well as knowledge of how to teach physics at the primary level. Within the course, emphasis is placed on the nature of physics teaching, learning at a qualitative level, and uses of qualitative models in interpreting the observations in nature as well as in the laboratory. The qualitative level examination is challenging even for student teachers majoring in physics.

Student teachers take the perceived shortage of subject knowledge hard. Tosun (2000) refers to Koballa and Crawley who offered a scenario that primary school teachers' belief of low ability to teach science is connected to negative attitudes towards science, and therefore teachers avoid teaching science. In the previous Framework curriculum for comprehensive school (FCCS, 1994) a subject called *environmental and natural studies* for grades 1 to 6 integrated biology, chemistry, geology, and physics. Because of the limited subject knowledge of physics and chemistry, teachers tend to focus on geography and biology, ignoring physics and chemistry contents. The novel National core curriculum for basic education (NCCBE, 2004), emphasising physics and chemistry, forces teachers to focus on chemistry and physics at grades 5 – 6.

Therefore, increase in the student teachers' ability in physics, in particular increase in their perceived physics-related self-efficacy, is an important objective for the course and its evaluation criterion. Hawkins (1995) emphasised that self-efficacy is a good predictor of behaviour in several areas, from bulimia to university faculty research productivity. According to Bandura (1997), self-efficacy is "judgement of one's ability to organize and execute given types of performances, whereas an outcome expectation is a judgement of the likely consequence such performances will produce" (p. 21). The perceived self-efficacy is not focusing on one's skills, but it is focusing on one's ability to do something in the certain situation.

While undertaking the physics didactics course, student teachers face several demands that will affect their perceived physics-related self-efficacy:

1. The demand that they learn physics concepts at the qualitative level. To exaggerate, student teachers need to learn thoroughly the physics that they should teach in the primary school.
2. The demand that they learn practical work teaching methods or models of conceptual change etc. However, this is less demanding than previously, because student teachers have quite deep understanding about learning in general.
3. The demand that they change opinions that learning physics is not only (and at the primary level at all) solving abstract problems using formulas. Physics is an endeavour to explain phenomena with models.

Therefore, the physics didactics course should be designed in such a way that it increases student teachers' perceived physics-related self-efficacy.

Overall, the situation is not as bad as the above account might suggest. For the class teacher education programme, there have been at least ten times more applicants than study places. Thus, our student teachers' readiness for challenging studies is good and they are highly motivated. Because of the scheduling of our teacher education programme, student teachers who participate in the physics didactics course have studied about 20 sp subject didactics of mathematics and art and craft as well as 20 sp of general education. Thus, student teachers have rather deep understanding about the general principles of teaching and learning (algemaine didaktik). Therefore, it is well-grounded to focus on the physics content to be taught in primary school physics, offering at the same time ideas on how to organise teaching and learning.

## Research question

In what follows, the physics didactics course is described and evaluated. The research question for the present paper focuses on evaluating the course from the point of view of self-efficacy. To what extent is participating student teachers' perceived physics-related self-efficacy increased during the course?

## Physics didactics course

The purpose of the course was to help students learn the basic concepts and principles or models of physics: Newtonian mechanics, electric circuits, energy and thermodynamics, as well as various skills, including laboratory and social skills. The course consists of several elements: lectures, group activities in the laboratory, and autonomous learning of literature in the web portal as well as essay writing.

Objectives for 5th and 6th grade physics education, presented in the NCCBE (2004), can be summarised as for example Millar (2004) and Hodson (1996) have suggested.

The aims of physics education at grades 5 and 6 in the Finnish primary school are to

- Help students to gain an understanding of basics of physics knowledge as is appropriate to their needs, interests and capacities:

  *The pupils will learn to use physics concepts in describing, comparing, and classifying.*

- Core contents in physics are:

  Energy and electricity

  - producing heat, light and motion with the aid of electricity; safety with electricity
  - various ways of producing electricity and heat; energy resources

  Scales and structures

  - the earth's gravity and friction, and motion and equilibrium phenomena due to forces
  - moving about safely and preventing accidents
  - motion of the earth and moon, and the resultant phenomena; structure of the solar system; the night sky.

- Develop pupils' understanding of the methods by which scientific knowledge has been gained, and our grounds for confidence in it (knowledge about science): *The pupils will learn to make observations and measurements, to look for information on the subject of study, and to weigh the reliability of the information.*

- Develop pupils' working and co-operative skills needed in practical work: *The pupils will learn to carry out simple scientific experiments clarifying the properties of phenomena, organisms, substances, and objects, as well as the correlations among them.*

The NCCBE (2004) emphasises the role of models and modelling in science teaching at all levels, from the primary level to the upper secondary level. In accordance with Giere (1991) NCCBE (2004) describes how concepts and natural laws can be created through interaction between the real world objects and the world of models as described in Figure 2. From the point of view of learning, pupils simultaneously use a range of explanatory models or mental models as described in the book edited by Gilbert and Boulter (1998).

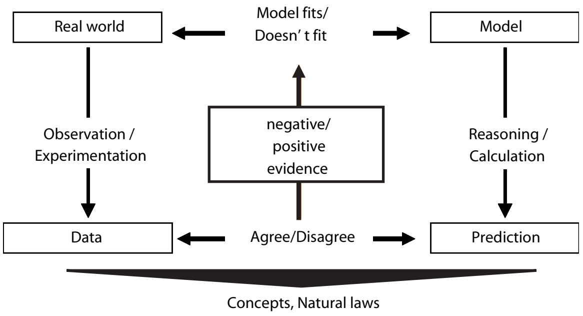

***Figure 2. The model used to describe how scientific concepts and natural laws are created (cf. Giere, 1991).***

By observation and experimentation a pupil can collect data on the 'real world' phenomena. Alongside this, the pupil conjectures explanations for the behaviour of this real world based on his or her mental models. From these models, a pupil may be able to deduce a specific prediction and compare it with the data. If the data and the prediction are in agreement, they increase the pupil's confidence in the match between the explanation and the real world. If they disagree, they may lead the pupils to question the explanation. Therefore, in the NCCBE (2004) it is stated: "*The starting point for instruction in physics (at grade 5 and 6) are the pupils' prior knowledge /mental models, skills and experiences, as well as their observations and investigations of natural phenomena, objects, and materials. From these, progress is made towards the basic concepts and principles of physics*".

## Qualitative level physics

One goal of the course was that student teachers learn physics concepts at the qualitative level. Student teachers were presented with Newtonian basic laws to describe and explain the change of motion; electric circuits; basic ideas of thermodynamics; and the idea of energy conservation.

### Newtonian laws

Hestenes (1992) suggested an approach to overcome misconceptions in Newtonian mechanics. Qualitative models are given to pupils as tools for representing and explaining movement phenomena. He claimed that in textbooks, background assumptions are described only indirectly, as they are considered obvious. In addition, qualitative level descriptions are typically omitted from textbooks. The books very rapidly represent and explain movement at the quantitative level (calculation exercises). He recommended that physics teaching should utilize qualitative models. Table 1 shows the qualitative models and related students' typical misconceptions emphasised during the course.

***Table 1. Newtonian laws in qualitative level and related typical misconceptions***

| Students' conceptions | Newtonian model |
|---|---|
| Three entities: physical bodies to move, mover (e.g. living body), and Earth that does not move | Every object can be idealised as a rigid body |
| Time and space: Vertical motion is primary and time is defined by the experiences of those who experience | Time and space is the same for every observer. There is no primary direction or place. |
| Foundation for perception is a living body on Earth that does not move | Foundation for perception (reference frame) can be chosen arbitrarily. |
| Impetus: a force, energy or power keeping a body moving. Impetus is stored in a physical body. While a body moves, impetus wears out and movement stops. | I: A body free from interaction does not change motion. |
| Active force: Active party (living body, motor, or other mover) is able to create motion. | II: To change motion, (net) force is needed. Change of motion (acceleration) depends on quantity of interaction (force), and inertia (mass) of bodies. |
| Dominance: In interaction, a bigger, more massive, or more active party exerts larger force. | III: Interacting parties experience equal, but oppositely directed forces. |
| There is no force directed towards a motionless object | Balance principle: If an object is in balance, forces directed towards it compensate each other |

### Electric circuits

Students' understanding about concepts related to electric circuits depends on whether or how they separate different concepts from each other or from the general everyday concept "electricity" (Arnold and Millar 1987, Psillos and Kouramas 1988). Therefore, it is important to guide them to understand that voltage of a battery is the cause and current in the circuit the effect, and, moreover, why the bulb (the resistance of the bulb) has an effect on the value of the current. Further, we have adopted the view that it is important that the students are guided to approach the subject of electric circuits holistically and to see that change of a bulb or the addition of a new bulb affects the whole circuit.

### Thermodynamics

There has been much interest in learning of the basic ideas of thermodynamics even in computer-supported environments (e.g. Vosniadou and Kollias 2005). We emphasize starting with the basic principles of thermal equilibrium i.e. the Zeroth Law of Thermodynamics and the inaccuracy of sensing warm and cool temperatures. The Zeroth Law states that when two bodies are both in thermal equilibrium with a third body, they are also in thermal equilibrium with each other. This is the basis of temperature measurements as the *third body* can be also a thermometer. Being in thermal equilibrium means that if they were brought in contact, there would be no transfer of thermal energy between them.

### Energy

Typically, the basic idea of energy is introduced by the capacity of a physical system to do *work* or as a term to express the power to move things, either potential or actual. Instead of this typical approach, we introduced energy through the conservation of energy. Several situations, like burning of firewood billets, photosynthesis, a torch and a pendulum, were analyzed and discussed with regard to how one form of energy was transformed into another. For example, it was explained how a battery converts chemical energy into electrical energy, which can be converted into light and thermal energy. Similarly, potential energy is converted into the kinetic energy of the moving water and turbine in a dam, and this in turn is transformed into electric energy by the generator. Simultaneously with the idea of conservation, the second law of thermodynamics was introduced: in every energy transformation, a proportion of useful energy is transformed to thermal energy. These basic two models of energy were illustrated by an energy caption as described in Figure 3. Deeper understanding about concept *energy* was approached for example by making a mixture of waters with different temperatures and by analyzing the motion of a bicycle.

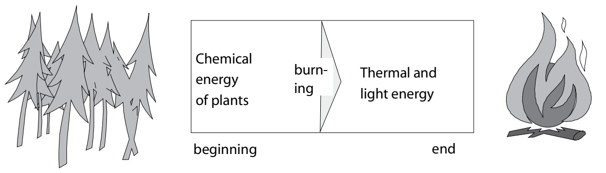

***Figure 3. Energy flowchart***

## Learning Methods Used During the Course

The course consists of several elements: lectures, laboratory activities, autonomous learning of the literature in the web portal and writing an essay. The basic idea is to produce a cognitive conflict that facilitates student teachers' thinking.

Posner, Strike, Hewson and Gertzog (1982) introduced a model about conceptual change based on cognitive conflict, or anomalies. According to their model, when students face an anomaly, they become dissatisfied with their concept, and thus acquire a new, better formulated concept through teaching. The teaching strategy consists of five aspects: 1) lectures, demonstrations and lab work should create cognitive conflict in students; 2) teachers should concentrate on diagnosing errors in pupils' thinking; 3) teaching should focus on creating strategies for dealing with student errors; 4) teaching should help pupils to make sense of science content using verbal, mathematical, concrete-practical, and other representations; 5) evaluation methods should help trace the process of conceptual change. According to Posner et al. (1982) "the content of science courses should be such that it renders scientific theory *intelligible, plausible, and fruitful*" [italics added] (Posner et al. 1982, 225). However, it seems that Posner's et al. model for cognitive conflict is too straightforward, assuming that change is more rational than the latest research implies. Student motivation, affect, beliefs, and attitudes seem to influence conceptual change (Sinatra and Pintrich 2003). Thus, during the course, positive atmosphere was emphasised.

During the lectures and laboratory activities co-operative learning methods were used. Johnson and Johnson (1994) defined five essential elements which characterise co-operative learning methods: 1) positive interdependence, when an individual is not able to succeed in a task without working with others; 2) face-to-face promotive interaction, where students assist in each other's learning and participate equally; 3) individual accountability, where every group member has their own responsibility for assessment; 4) social skills, where pupils should be trained to work together effectively; and 5) group processing, where group members evaluate their own work.

During the course, the *think-pair-share* co-operative learning method was used to facilitate student teachers' thinking of the basic models of physics and conceptual change with cognitive conflict. (1) Students individually thought about a topic provided by the teacher. (2) Each student was paired with another student to discuss it. (3) They shared their thoughts with another group or with the class (cf. Kagan & Kagan, 1994). Student teachers were presented with problems and arguments that are typically used to clarify children's pre-conceptions (see Figure 4). In the laboratory, student teachers obtained experiences concerning phenomena addressed in the problems. In order to spare time for deep discussion about the meaning of the qualitative models of physics and discussion of organising the learning in a classroom concerning the topic, student teachers conducted a relatively small number of laboratory activities in the small group.

***Table 2. Example of an argument used to facilitate small group discussions***

**Two same-size balls (the dark one is twice as heavy) are dropped at the same time**

**Argument:** They will hit the ground at the same time

Moreover, during the past few years, we have developed a web portal facilitating subject knowledge learning. The portal provides texts, audio files, figures, and animations. The design and development of the portal is described in Juuti, Lavonen, Kallunki and Meisalo (2004). The web portal supplied the literature for the final examination. In addition, student teachers were asked to write an essay (about eight pages). They autonomously chose one physics concept studied during the laboratory activities and designed a teaching plan for the concept.

## Method

The physics didactics course was held during the autumn 2005 (from September to October). At the beginning of the first lecture, student teachers were asked to complete a questionnaire measuring their perceived physics-related self-efficacy. Several participants complete the questionnaire between the first and the second lecture. Student teachers were told to think of their present (or past, remembering school times) perception of their abilities. At the end of the course, during the examination, student teachers were asked to completethe same questionnaire. We emphasised several time that answers to the self-efficacy instrument have no influence on the grade.

Although 102 student teachers were enrolled for the course, only 79 students participated in the final examination. The lectures are optional, thus it appeared that only 70 student teachers (8 male, 62 female) participated in both the pre-test and post-test.

To measure student teachers' perceived physics-related self-efficacy, we adopted the seven-item instrument designed by Tuan, Chin and Shieh (2005). The student teachers were asked to take a stance on the following statements (using a five point scale): 1) Whether the science content is difficult or easy, I am sure that I can understand it. 2) I am not confident about understanding difficult science concepts (-). 3) I am sure that I can do well on science tests. 4) No matter how much effort I put in, I cannot learn science (-). 5) When science activities are too difficult, I give up or only do the easy parts (-). 6) During science activities, I prefer to ask other people for the answer rather than think for myself (-). 7) When I find the science content difficult, I do not try to learn it (-).

The final examination contained two questions: (1) Design a teaching sequence for which the objective is the learning of Newton's third law. (2) Produce a concept map of the coupling of bulbs and batteries. For the course grade, the weight of the first question was 65%, the second 25% and the essay 10%. Student teachers' examination outputs were assessed before the questionnaires were analysed.

Results and discussion

The means of the pre-test and post-test distributions were compared using the paired-samples *t*-test. As an additional check, we tested the power of the difference using Cohen's $d$ $\{d=(M_g-M_b)/S.D._{pooled}$, where $M_g-M_b$ represents the difference between the means and $S.D._{pooled} = \sqrt{[(S.D_g^2 + S.D_b^2)/2]}\}$ (Cohen, 1988). The paired-samples *t*-test is used to test the hypothesis of no difference between two variables. Cohen's *d* measures the effect size for the difference between post-test and pre-test: no effect at $d<0.2$, small effect at $0.2 \le d < 0.5$, moderate effect at $0.5 \le d < 0.8$, and large effect at $d \ge 0.8$.

The student teachers' perceived physics-related self-efficacy increased from the mean value 3.2 (*Std.* 0.76) to 3.5 (*Std.* 0.63) ($t=-3.4$, df=69, $p<0.01$). There was a small effect with regard to the increase in self-efficacy ($d= 0.3$).

The scale for the course grade was from 0 (fail) to 5 (excellent). The mean for the course grade was 3.1 (*Std.* 0.63). There was no statistically significant correlation between gender and grade. There was the expected inter-correlation between gender and self-efficacy (Pearson correlation 0.24, $p<0.05$). It was unexpected that there was no statistically significant inter-correlation between self-efficacy and grade.

These results are now discussed. During the physics didactics course student teachers' perceived physics-related self-efficacy increased. However, the increase was small. According to Bandura (1997) self-efficacy is a good predictor of action. After the course, it should be expected that student teachers are ready to prepare primary school physics teaching from the point of view of subject knowledge. However, the perceived self-efficacy at the beginning of the course was not very low; it was above three. During the course, the mean value of the perceived self-efficacy increased and the standard deviation diminished. Perhaps student teachers, after the course, felta little more capable in physics.

As indicated above, there was no statistically significant correlation between self-efficacy and grade. The explanation could be the focus of the instrument. The course focused on both subject knowledge and teaching and learning of physics; the self-efficacy instrument focused only on perceived self-efficacy in subject knowledge. Tosun (2000) examined student teachers' experiences from previous science studies. Tosun found that student teachers' experiences about science were very negative. Tosun refers to Bandura's sources of efficacy expectations: performance, vicarious experiences, verbal persuasion, and emotional arousal. The performance accomplishment was seen the most important source of self-efficacy. Although, during the course, there was a positive emotional atmosphere, there was perhaps too minor a facilitation of the feeling of competence. The examined physics didactics course focused on cognitive conflict. Student teachers were presented arguments emphasising typical incorrect preconceptions (see Figure 4 and Table 1). The goal was to facilitate cognitive conflict, but the outcome appeared to be the facilitation of a feeling of incompetence with regard to physics.

The problem with the perceived physics-related self-efficacy instrument is that there is no reference point. Student teachers evaluate their ability in physics on the scale one to five. There is a question as to how the mean value of self-efficacy should be interpreted. Perhaps the scale was too rough. Bandura (1997) suggest that instrument needs to be differentiated. It would be interesting to compare several subject didactics courses with the more differentiated instrument. However, Bandura (1997) stresses that contextless measures of self-efficacy are not good predictors of action; therefore, universal instruments are not useful. The competence area should be explicitly stated.

In the future, the physics didactics course should emphasise the student teachers' feeling of success in physics as well as physics education. Even the use of co-operative learning methods and the role of the peers was not fully developed. During the course, ad hoc grouping was used. Perhaps in the future, permanent groups would show the advantages of learning communities (cf. Meisalo, Lavonen & Juuti, in press) enhancing physics-related self-efficacy.

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