RÅDET FÖR HÖGRE UTBILDNING
COUNCIL FOR THE RENEWAL OF HIGHER EDUCATION

Project number: 063/G02
Name: Associate Professor Ingvar Thorén
Institution: University College of Gävle
S-801 76 Gävle
Tel: +46 (0)26 64 87 49
E-mail: itn@hig.se

Professional teacher knowledge in mathematics and science - development from student to teacher

Abstract

We are going to develop the teacher education programme for compulsory schoolteachers in mathematics and science. The prospective teachers are to study mathematics and science out of a teacher's perspective. That means making them aware of the alternative views of scientific phenomena held by children and engage them in serious reflection on how this knowledge about children's ideas guides the transformation of subject matter content in the planning of instruction. Subject matter knowledge and pedagogical content knowledge will be explicitly expressed, integrated and structured in a way that gives the prospective teachers a progressive development of their teacher knowledge base. We will identify and focus on central multidisciplinary concepts in order to achieve a holistic view of science.

School-practice and theory will be co-ordinated to give the prospective teachers opportunities to reflect on practical teaching situations and student responses. Experiences of how pedagogy and content knowledge interact will be analysed and discussed in seminars together with their tutors and teacher educators. Both content and strategies in the programme will be evaluated and analysed in order to improve the prospective teachers' learning. The project is connected to and benefits our ongoing research project in mathematics and science education - "The progression of Pedagogical Content Knowledge during the teacher training programme in Science and Mathematics".

Keywords: teacher education, pedagogical content knowledge, mathematics, science.

Developing Transformative Pedagogical Content Knowledge in Science and Mathematics Teacher Education

Ingvar Thorén, Eva Kellner, Annica Gullberg and Iiris Attorps, University of Gävle, Sweden.

Abstract
Pedagogical content knowledge (PCK) is an important part of a teacher's knowledge base.
For that reason, we have studied the PCK involved in the natural science and mathematics courses of the teacher education programme for primary and lower secondary school. Both the prospective teachers and their teacher educators had to complete questionnaires that were analysed. The result reveals a number of interesting differences between the prospective teachers' and their educators' conceptions of PCK. We then started to further develop courses where subject matter and PCK are integrated. This paper will present the process of developing the mathematics and science courses in the teacher education programme in order to create a transformative kind of PCK.

Introduction
Teachers in science and mathematics for primary and secondary school are educated at the University of Gävle. Besides the courses in general subjects of teacher education, common to all prospective teachers, one year is designed for courses in natural sciences, technology and mathematics organised in eight different courses. In order to get subject matter, pedagogy and practice integrated in these courses we have started our project.

According to findings from the last years' research in science education, we intend to revise the courses in order to make the prospective teachers better prepared for their further professions as science and mathematics teachers in the compulsory school.

We address this paper to teacher educators in science and mathematics who are interested in developing new ideas.

Background

Pedagogical content knowledge

Since Shulman (1986) introduced Pedagogical Content Knowledge (PCK) as

> "The most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others"

it has been used to describe a teacher's base of knowledge as the knowledge that distinguishes a teacher from a subject matter specialist. PCK – the conglomerate of subject matter, pedagogy and context – has highlighted the importance of subject matter knowledge and its transformation into teaching matter and PCK is also helpful to create models of teacher knowledge.

The model of teacher knowledge was further developed by Shulman (1987) and Grossman et al (1989). In her book "The Making of a Teacher" Grossman (1990) presented a model in which PCK is a central part together with other domains, subject matter knowledge, general pedagogical knowledge and knowledge of context, which are reciprocally interacting with each other.

Gess-Newsome (1999) describes two extreme models of teacher knowledge, the Integrative and the Transformative model.

In the Integrative model PCK does not really exist as an own domain and teaching is seen as an act of integrating knowledge of subject, pedagogy and context. When teaching in the classroom, knowledge from all these domains is integrated by the teacher to create effective learning opportunities. Traditional teacher education programmes, organised in separate courses of subject matter, pedagogy and practice, often follow this model of teacher knowledge.

In the Transformative model PCK is the synthesis of all knowledge needed in order to be an effective teacher. PCK is then the transformation of subject matter, pedagogy and contextual knowledge into a new form of knowledge that is more powerful than its constituent parts. This model will support teacher education programmes containing purposefully integrated courses in which the prospective teachers quickly develop needed skills and knowledge.

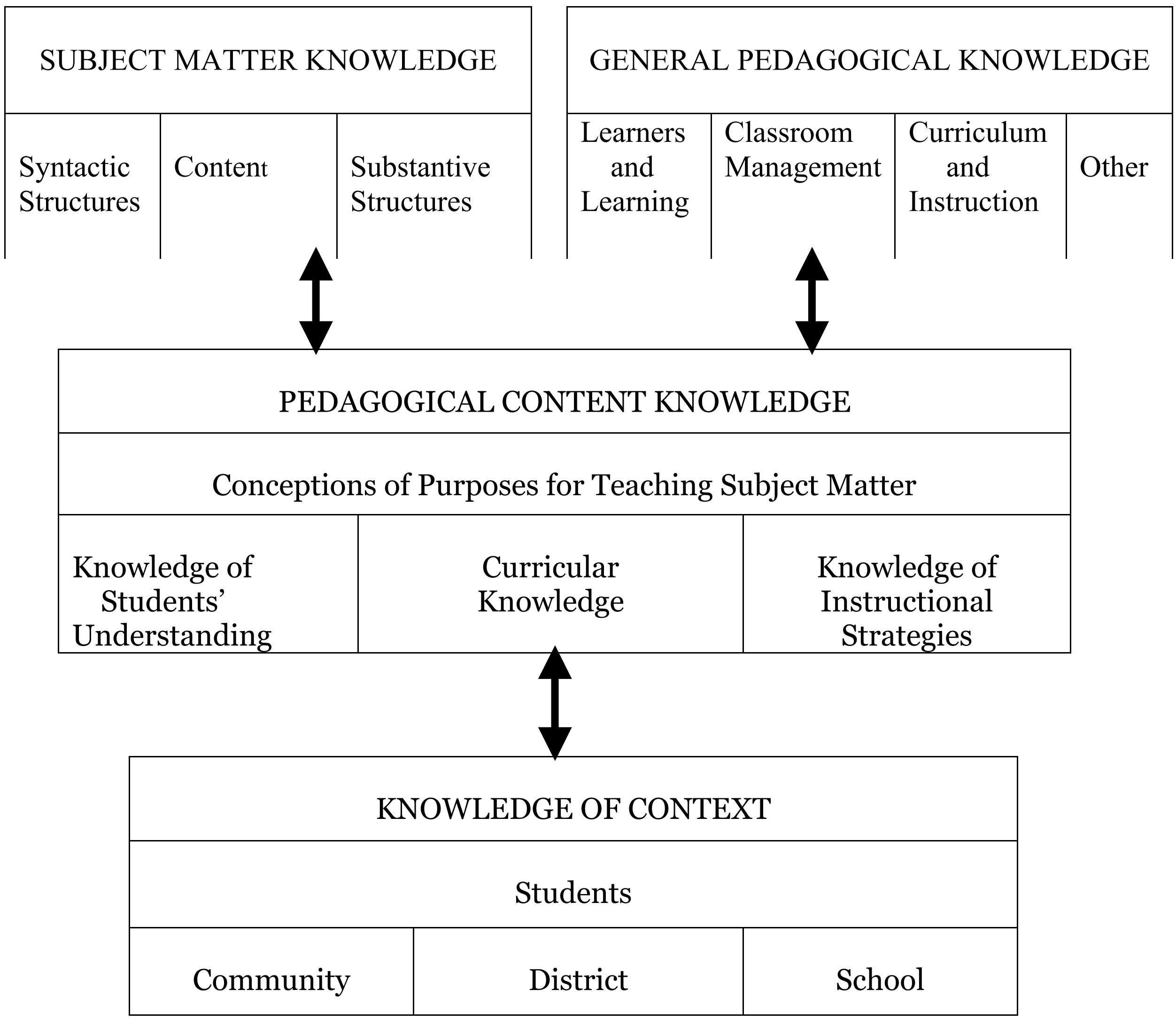


Figure 1: Grossman's model of teacher knowledge 1990).

In Grossman's model (figure 1) PCK is given a structure containing the overarching idea of teaching, knowledge of students' conceptions and difficulties, knowledge of curriculum and knowledge of strategies and representations. A rather simple structure of a very complex domain of knowledge – the teacher's knowledge base. However it is useful in research and in the construction of teacher education programmes.

PCK in science teaching
According to Grossman's model Magnusson et al (1999) developed a little more sophisticated model of PCK for science teaching. The unique knowledge for teaching that distinguishes a teacher from a subject matter specialist is seen as a transformation of several types of knowledge. They state, that teachers with integrated knowledge will have greater ability to design and guide learning processes to help students in developing scientific knowledge than those whose knowledge is limited and fragmented. Since not only teachers' knowledge but also their beliefs have a great impact on all aspects of teaching, teachers' beliefs in different domains of knowledge have been taken into account. Assessment of scientific literacy is seen as an important part of teacher knowledge and is of that reason given an own domain in the structure of PCK.

In Magnusson's et al (1999) modified model for science teaching the component "overarching ideas of teaching" is changed to "orientations toward science teaching", which refers to teachers' knowledge and beliefs about the purposes and goals for teaching science. An orientation represents a general way of viewing science teaching. Knowledge and beliefs in this area will guide a teacher's decisions about organisation of activities, use of curricular materials, content of student assignments and evaluation of student learning. Orientations toward teaching science have been identified in the literature and can be organised according to the emphasis of the instruction from purely process or content to those that emphasise more student-centred discovery- or inquiry-based goals. Though most teachers may hold multiple orientations with incompatible goals and purposes, this component of PCK is important for teachers' decisions about planning, enacting and reflecting upon teaching and their possibilities to accept new curriculum projects and use new curricular materials.

Knowledge and beliefs about students' scientific preconceptions and difficulties, but also what knowledge and skills are needed for learning a specific topic are essential for teacher in their planning and pursuing their teaching. Science curricula with goals and objectives state what is to be done and the teacher has to decide what strategies and representations are the best for each subject and specific topic. Of course knowledge of this domain is very important but so is also knowledge of curricular and laboratory materials for effective teaching.

Teachers have also to assess the students' learning. Of that reason they must know what is to be assessed and which method that is appropriate in assessing each topic and type of knowledge and skills. Thus assessment of science is a natural part of PCK.

Subject matter knowledge
Shulman (1986) in his paper "Those Who understand: Knowledge Growth in Teaching" highlighted the "missing paradigm" in educational research: subject matter knowledge and teachers' knowledge about that. In most models for teacher knowledge, subject matter knowledge is a domain reciprocally interacting with PCK. Subject matter knowledge is then structured into substantive and syntactic areas (Schwab, 1978, Grossman, 1990), where substantive content knowledge refers to the

concepts, principles, laws and models in particular content areas of science. Syntactic content knowledge refers to the agreements, norms, paradigms and ways of establishing new knowledge that scientists hold as currently acceptable (Smith 1999).

Both kinds of subject matter knowledge are needed for teachers' development of PCK and their PCK will create questions, ideas and reflection that stimulate deeper insights in their subject matter knowledge and beliefs. In that way teachers will go on developing their knowledge bases in their future professions as teachers.

General pedagogical knowledge and knowledge of context

To get a realistic view of teaching in its full school context and shift from concern with self to concern about children's learning, prospective teachers must practice teaching in lessons that they plan, implement and evaluate. They need to understand and be able to use the general principles of good classroom management, form standardised routines for instruction and get knowledge of pupils' attitudes, interests and problems that are essential for effective teaching. This can only be acquired through extended classroom experience.

Initial practice should be provided in controlled forms as peer teaching, microteaching or some kind of case studies. But prospective science teachers need experience in classroom settings, observing experienced teachers and working with pupils individually and in small groups to develop their PCK.

PCK - implications for science and mathematics teacher education

The model for a teacher's knowledge base, described by Grossman et al (1989) and modified by Grossman (1990) can be seen as a platform for a teacher education programme. Especially for science-teachers subject matter knowledge, both substantive as well as syntactic (Smith 1999), is essential and can be transformed into PCK as described by Gess-Newsome (1999) and further developed especially for science teachers by Magnusson et al (1999).

Some critical amount of subject matter knowledge seems to be necessary to develop the PCK required for teaching. Integration of knowledge domains is important, as is exposure to examples of excellent teaching and multiple supported teaching experiences. Just simply telling teachers how to do does not provide sufficient support to enable them to put ideas into practice. They must have opportunities to learn in meaningful and supportive context. Integrating course content and field assignments are necessary to provide prospective teachers with integrated teaching knowledge. (Magnusson et al 1999)

PCK as the transformation of several types of knowledge for teaching is a heavy core of science teacher education and includes the following elements (Magnusson et al 1999):

- The goals of science education and their relationship to purposes for teaching science (knowledge of *orientations to teaching science,* knowledge of *science goals and objectives).*
- Instructional strategies that match particular orientations to teaching science (knowledge of *subject-specific strategies,* knowledge of *specific science curricula).*
- Planning, conducting and reflecting upon teaching specific science topic, guided by considerations of students' understandings (knowledge of *students' understanding,* knowledge of *science assessment)* and the appropriateness/value of using particular instructional strategies (knowledge of *topic-specific strategies).*

- Planning and administration of assessment that is compatible with one's orientation to science teaching and targeted goals and objectives (knowledge of *science assessment).*

The science teacher education project

Teacher education programme
In the programme for teacher education at the University of Gävle, science and mathematics teachers for primary and lower secondary school are educated. For admission to the programme prospective teachers must have passed advanced courses in physics, chemistry, biology and mathematics from upper secondary school. Therefore at the beginning of the programme they have a rather large amount of scientific subject matter knowledge. Of course it has to be deepened and suited for teaching during their time at the university.

During the study of natural sciences, technology and mathematics the prospective teachers are studying the school context for ten weeks containing six weeks of classroom practice and four weeks of other kinds of field based activities. Subject matter, pedagogy related to it and school context studies have to be integrated in order to educate good teachers. This sub-programme is organised in eight five weeks courses, each containing both subject matter, PCK and context studies.

To treat biology, chemistry, physics, technology and mathematics as one unit is not very easy. Many teachers with different specialities and views are supposed to co-operate, the connection between the university and the field is problematic and all teachers involved think that it is too little time for teaching. In that situation important parts of the curriculum for development of a science teacher's knowledge base are easily missed. We started a project in order to make an inventory of the content, create co-operation between subjects, integrate PCK in the courses and develop the communication between the university teacher educators and the teachers in the field. Our aim is to present a revised curriculum, in agreement with last years' research, better suited to the intentions of teacher education.

Inventory of course content
First of all we began to make an inventory of the content of all eight courses. We were interested to know the subject matter content but also the pedagogical content and how prospective teachers and their educators apprehended it. According to a model of science teachers' knowledge base (Shulman 1987, Grossmann 1990, Magnusson et al 1999) we constructed a questionnaire containing questions about topics in subject matter, pedagogical content and school-context. Prospective teachers had to state if the topic had been carefully treated and in which course it had been done. They also had to answer a couple of open-ended questions about content, teaching and organisation of the courses and give their personal opinion of the education. Their teacher educators had to state if the topic had been carefully treated or not, but also how many lessons they had spent on it, how they had been working with it and what literature had been used. Both prospective teachers and their educators had to complete the questionnaires at the end of the year when almost all courses were finished and only the examination of the last course remained.

Result of the questionnaires
There was agreement between the prospective teachers' and their educators' opinions about what had been studied in subject matter. Both substantive and syntactic

aspects had been treated in many courses, and also the difference between what you know is in agreement with scientific knowledge and what you only think is so, had been paid attention to.

Also about pedagogical content there was agreement between what the prospective teachers remembered had been done and their educators' statements of what really had been done according to their plans and documents. But in their answers of the open questions the prospective teachers stated that it was too much subject matter theory in the courses and too little working with strategies, representations, experiments and activities that can be used in the classroom. Especially they wanted more about strategies to handle pupils' difficulties to understand certain scientific topics. Most teacher educators however meant that it was too little subject matter theory in the courses and too much school based and pedagogical content. They also said that it was very little time for subject matter theory studies and almost everything done was suited for the classroom.

We also found that some areas were totally missed in all courses. Assessment of pupils' knowledge and conceptual development in science had not been studied and no methods of evaluation and assessment either.

Though many courses, according to the teacher educators' answers, contained topics where inquiry methods had been used and integration of subjects had been done, none or very few of the prospective teachers remembered that it had been practised or discussed. Neither had modern curriculum materials and interactive computer based materials been used and evaluated in an acceptable amount, according to the prospective teachers' opinions.

Modification of the programme

Before a new group of prospective teachers should start their one year long studies of natural sciences and mathematics we had a series of meetings with the teacher educators. We presented the outcome of the questionnaires and discussed the content of the courses and ways to modify the sub programme and make it more effective. Since lack of time always is a great problem in all courses we had to find out where time for the missing topics, first of all assessment and subject integrated studies, could be found. We found that the same experiments were studied in several courses, for example heat in physics and chemistry, electrical circuits in physics and technology and bio molecules in biology and chemistry. Through a jointed planning and co-operation between the educators time was saved and the missing topics could be put into the schedule.

The co-operation between the university and the schools was very weak and there were almost no possibilities for the teacher educators to visit the prospective teachers in their classrooms during the period of practice. Since connection to the school context is essential in teacher education we decided to further develop this contact in order to organise seminars before, during and after the period of practice in which the teacher educators, prospective teachers and their supervisors participated. At these seminars, that took place in different schools, pedagogical, practical and contextual questions were discussed and analysed.

Analyse
In order to evaluate the modified programme we decided to study the prospective teachers' professional development by letting them complete two questionnaires, when the first courses in mathematics, physics, technology and biology were studied.

We wanted to know the prospective teachers' beliefs about their own development from students to teachers. Then in each of the questionnaires we constructed 30 statements about their pedagogical knowledge and they had to note if they did agree or not in a five grade scale. As an illustration we will give three typical statements.

- I have changed my mind about the way I want to teach physics at school.
- Now I can explain physics in many different ways to get children understand.
- I have learnt a lot about children's conceptions of biological concepts.

Not at all	Little	Some	High	Very high
x	x	x	x	x

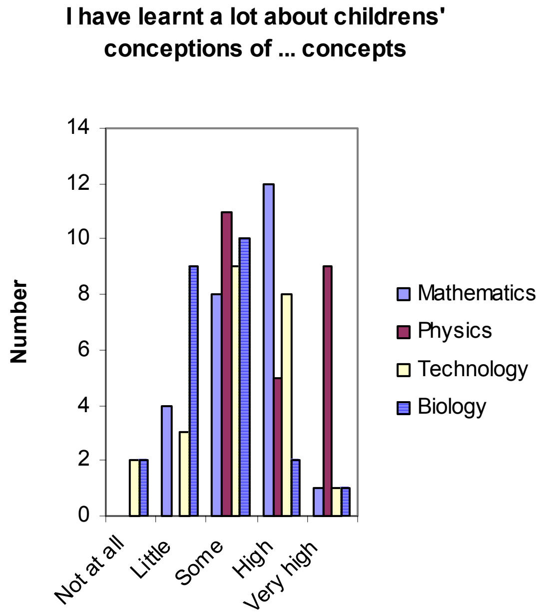
In this scale the prospective teachers had to set a mark in agreement with what they thought.

Each questionnaire also contained four open-ended questions about what the prospective teachers thought about their own development in subject matter and PCK. In each of the subjects mathematics, physics, technology and biology every prospective teacher had to give: *Some aspects of my development in subject matter knowledge and in PCK during this part of the programme.*

Outcome and discussion of the modifications

The questionnaires

The questionnaires gave us a lot of information about the prospective teachers' development, the courses and their content but also the advantages and disadvantages of the curriculum. In figure 2 – 5 we present a few examples from the analyses of the statements.



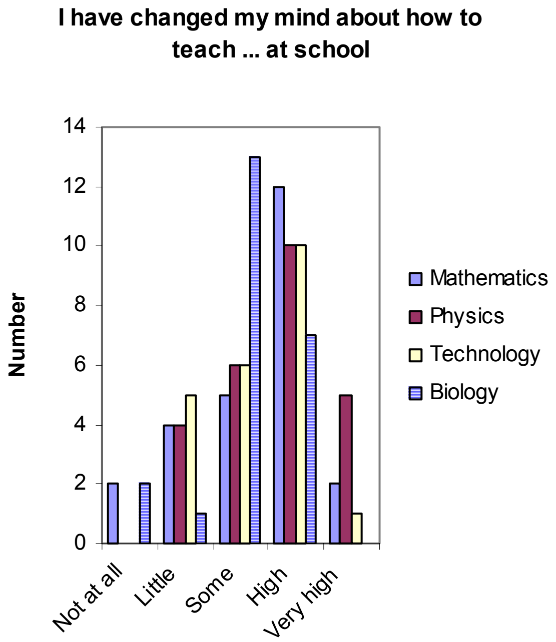


Figure 2: Prospective teachers state in what grade they have learnt a lot about children's conceptions

.

Figure 3: Prospective teachers state in what grade they have changed their minds about how to teach.

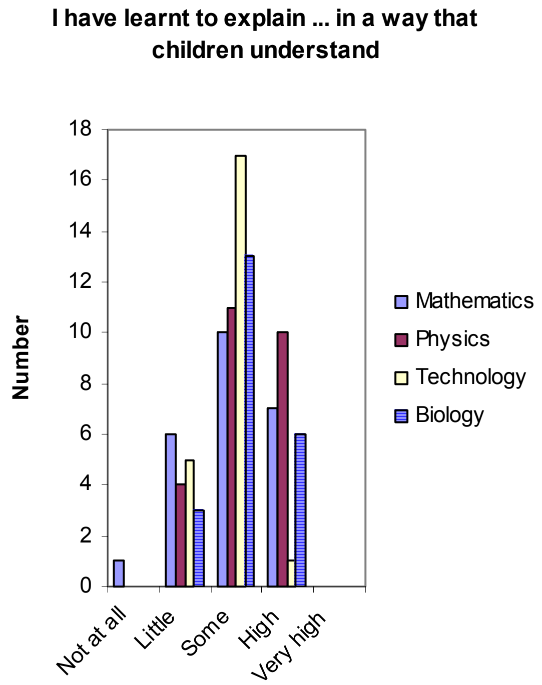


Figure 4: Prospective teachers state in what grade they have learnt to explain in a way that children understand.

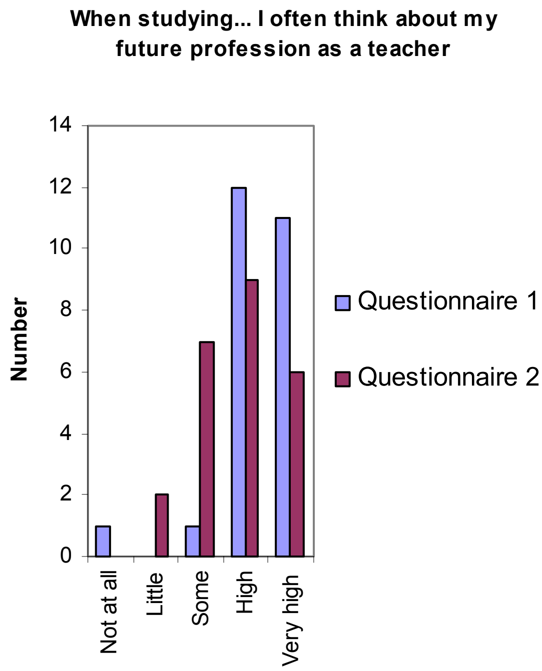


Figure 5: Prospective teachers state in what grade they, when studying, think about their future professions as teachers.

According to their own apprehensions the prospective teachers have improved their pedagogical content knowledge a lot. There are some differences between the courses but together they have improved the prospective teachers' knowledge in all domains. It is also apparent that the teacher educators have focused their attention on different parts of teacher knowledge. Some have emphasised subject matter, strategies, representations and activities suited for the classroom, but other have stressed students' preconceptions, difficulties and ways to handle it. Perhaps focus depends on teacher educators' experience of teaching. The more experience of teacher education the more complete and integrated teaching of both subject matter and pedagogical content.

Open-ended questions

Subject matter knowledge

Every prospective teacher could give *"Some aspects of my development in subject matter knowledge during this part of the programme"* in each of the subject's mathematics, physics, technology and biology. By analysing the answers of this open-ended question we found a variety of aspects given by the prospective teachers about their development of subject matter knowledge. Some of the prospective teachers had like Felix, Carola and Frida learnt new things, got a deeper understanding or started to reflect upon what happens in the nature. Also new practical moments like soldering, turning, milling and welding in technology and new experiments in physics seem to have been of great value for their development of teacher knowledge.

Felix says about his development in physics: *"I have learnt much more and in a different way than I did at school"* and Carola has for her first time met the subject technology and says: *"I have approached the subject technology, which I have never met before during my time at school"*. Frida, who especially got interested in biology, states "*This spring I really have noticed what is going on. Now, I am aware of what happens in the nature."* and Sally noted in technology *"We have experienced different things like soldering, turning, milling and welding"*.

Some prospective teachers state that they haven't got much new subject matter knowledge but have refreshed and brought their old knowledge up to light. Anna says about her development of subject matter knowledge in mathematics: *"Not very much. We have studied mathematics on a very fundamental level, which I think is the right thing. That is the key for a successful continuation."* and Vera means, *"I haven't learnt much new things but I have brought much old knowledge up to light"*.

Many prospective teachers state that they have improved their interest in mathematics and science and got to see the subjects in new perspectives. Martin says about his development in biology *"I have learnt a lot about birds and above all the course has aroused my interest."* Erik in physics *"It has never before been so nice to studying physics"* and Karin also in physics *"It has been so fun to see the subject physics from another perspective than sitting and solving problems"*.

Pedagogical content knowledge

Every prospective teacher also could give *"Some aspects of my development in pedagogical content knowledge during this part of the programme"* in each of the subjects mathematics, physics, technology and biology. By analysing the answers of this open-ended question we found a variety of aspects given by the prospective teachers about their development of PCK.

Many prospective teachers are very fond of all tips about methods, activities, experiments, textbooks and teaching aids, useable in the classroom, which they have got in different courses. Felix for example says "*I have got many good examples of methods to be used in common teaching and in the carrying out of experiments"* and Martin about his benefit from the biology course *"I have got many good tips and ideas to practical outdoor-activities for children"*. Tina thought that *"The studying path in the nature was very good"* and Peter found that the practical experiments in technology were very useful by saying *"We have had many practical experiments from which I have learnt a lot"*. Hanna experienced how she could feel like a pupil in mathematics *"He let us feel how it is to be a pupil and test other types of teaching aids"* and found that very valuable.

Knowledge about children's preconceptions, of how to create interest and motivation in the class, and explain mathematics and science for the children was emphasized by many prospective teachers as very valuable ingredients of the courses. Anna says about her development of PCK in mathematics *"A very great progression. I have got a rather new understanding about young children's thinking"* and Eva *"Before I explain things I can think what the children think"*. Vera found in the physics course *"the possibility to make physics fun for the children"* and Karin in the technology course *"How you in a simple way can explain for the children the history of technology and what happens in different wiring diagrams"*. Some other prospective teachers highlighted the study of the curriculum like Erik in technology who says *"Interesting to study the curriculum"*.

New ideas about teaching mathematics and science and a new perspective on the goals of the teaching are expressed by Carola who says about the course in mathematics *"Here I have got so many different ways and teaching aids that can be used to get the children understand"* and Anna saying *"A rather new view. It is the pupils' understanding that comes first"*.

Although the majority of prospective teachers mean that they have developed their PCK very much, other state that they are displeased with the pedagogical parts of the courses. Lena and Karl may represent those ideas when they describe their development of PCK. Lena: *"Very much didactic development. I want to learn much more. It feels as if it will be very much more to learn"* and Karl: *"I don't think we have got in contact with the didactic part very much. The pedagogical content is missing"*.

According to our study of the first four courses in science and mathematics, it seems, as if our intentions about the integration of PCK have been fulfilled. The prospective teachers think, when studying, about their future professions as teachers and state that they have got new ideas about how to teach. They also have learnt a lot about children's conceptions and difficulties and ways to handle it. A new perspective on elementary subject matter knowledge, in combination with methods to use it in experiments and other activities suited for the classroom, have given the prospective teachers a positive attitude to science and mathematics.

Practice and school context

We took part of all the seminaries before, during and after the period of practice, and noticed what was said in the discussions. After the seminar the prospective teachers had to complete a questionnaire about their new experiences of teaching, of pupils' conceptions and difficulties, and of methods to assess conceptual development in science and mathematics. In short interviews, that were audio taped, they had to explain their answers and tell us about their experiences of the period of practice.

Though we had a meeting, in which teacher educators, prospective teachers and their supervisors took part, just before the prospective teachers went to their classroom practice, we found that an effective cooperation between the university and the schools is hard to achieve. The supervisors wanted much more information about the objectives of the practice and of the courses at the university than they had got. They also expressed the need of information in time to be able to plan a schedule that will fit the prospective teachers' practice in certain subjects and special tasks. In order to get the practice function well they must, as supervisors, give the prospective teachers a lot of support and have to carefully prepare the period. That requires a good communication between them and the teacher educators at the university.

The meeting before and the seminaries during the period of practice were of great value to straiten the cooperation but the supervisors would like to meet the prospective teachers now and then during the courses in order to create a closer relation between them and their classes. But, as they also have loyalties to their pupils and their colleges it is often hard for them to visit meetings at the university.

Almost all the prospective teachers think that the classroom practice is very valuable for their development in teaching. They experienced as if they at the university are studying an idealised world but in the classroom meat reality, and learn a lot about children's behaviour, difficulties and possibilities. During the six weeks of practice they also got to know the pupils as individuals and could of those reason better handle situations in the classroom. By discussing their teaching after each lesson they had got much experience of how to behave in the class and of how to evaluate their own teaching. Sara said: "*I got to know how I was as a teacher. I didn't know that before*".

Through the classroom practice the prospective teachers could find out what the children knew in science and mathematics and they often like Tom found that *"the children are at very different levels"*, or as Maria said *" I have learnt very much about the pupils thinking about electricity"*. They also expressed their increasing experience of how to evaluate pupils' conceptual development in science and mathematics. *"You can't only count the points but you have to look at the content and the pupils' understanding and development of conceptions"*, as Karl said. Some were concerned about pupils' difficulties in mathematics and about what to do and felt like Robert who said, *"I can explain in one or two ways, but in the third and the fourth way I can't. We need more knowledge about how to explain fundamental things in different ways"*.

We found from our study that the modifications of the practice improved the communication between the university and the schools but that it must be further developed. Better information about courses, clearer objectives for the practice and regular communication between teacher educators, prospective teachers and their supervisors are essential in the process to create good cooperation. For example could the prospective teachers in each course now and then visit the school for their classroom practice in order to get to know their supervisors and classes, exchange information and prepare the period of practice.

Evaluation and assessment of children's conceptual development had been dealt with and almost all the prospective teachers seem to have increased their experiences of how to handle that issue. But different methods for assessing different aspects of knowledge must also be studied and put into the courses.

Construction of a new curriculum

Intentions

Based on Grossman's (1990) and Magnusson's et al (1999) models of teacher knowledge and all the information we got from our study, we want to construct a new curriculum for the science and mathematics teacher education at the University of Gävle. We want to reduce the number of courses, strengthen the integration of subjects and get the teacher educators to co-operate in producing a holistic knowledge base for the prospective teachers. By increasing the co-operation between the university and the field we hope, that the prospective teachers' practice shall be more efficient and connected with the theory studied. In-depth subject matter studies suited for the school context, topic-specific strategies and representations, assessment and methods suited for different orientations of teaching will influence the development of transformative PCK.

PCK for the teacher education programme

In agreement with Magnusson et al (1999) we describe pedagogical content knowledge as the transformation of several types of knowledge for teaching (including subject matter knowledge), and as such it represents a unique domain of teacher knowledge. Pedagogical content knowledge is a result of the interaction of content and pedagogy and
it is important to realize that thorough and coherent understanding of subject matter acts as a prerequisite, preceding the development of PCK.

It appears that the craft knowledge guiding experienced teachers' classroom practice is constituted by a framework integrating knowledge and beliefs about the teaching and learning of science, the nature of science, subject matter and students. A crucial factor in this development is, obviously, teaching experience. This explains why prospective teachers usually express little or no PCK (Lederman et al., 1994).

Prospective teachers are usually keenly aware of their need to acquire knowledge and skills in the area of general pedagogy for example motivation and classroom management. However, they are usually surprised to discover that there are many aspects of content knowledge relevant to the task of teaching that they need to acquire. Teachers must be able to explain real world phenomena, but many teachers may not have the subject matter knowledge needed for developing desired pedagogical content knowledge in that area. Just as students' existing knowledge and beliefs serve as the starting point for their learning, it is important for teacher educators to understand prospective teachers' conceptions and alternative conceptions about the teaching of science. But without strong connections between content studies and methods studies, the transformation of subject matter knowledge necessary for teaching cannot occur. Teacher education programmes also must provide opportunities to use PCK in teaching situations and to reflect on these practical experiences (Clermont et al., 1993).

Instead of generating checklists with indicators of effective instruction, we want to provide teachers with a knowledge-base which enables them to teach specific topics effectively and flexibly in all situations that will occur in the classroom. We intend to shift the focus of learning to teach from the ordinary acquisition of a set of classroom management and knowledge transmission skills, to the more demanding but intellectually satisfying task of inquiry into how pedagogy and content knowledge interact.

Subject matter knowledge for teaching

Subject matter knowledge, that influences the teaching and learning of prospective teachers, include content knowledge, substantive knowledge, syntactic knowledge, and beliefs about the subject matter (figure 1). Content knowledge refer to the "stuff" of a discipline: factual information, organising principles, central concepts. (Grossman et al., 1989)

Prospective teachers must understand the centrality of content knowledge for teaching and the consequences of a lack of knowledge, but also the need to learn about the central concepts and organizing principles of a subject matter. Academic disciplines do not simply consist of concepts and organizing frameworks, but include also knowledge of the ways in which new knowledge is brought into the field. These syntactic structures are the canons of evidence that are used by members of the disciplinary community to guide inquiry in the field.

Teachers who do not understand the role played by inquiry in their disciplines are not capable to adequately representing and, teaching that subject matter to their students.

Without a firm grasp of the syntax of a discipline, prospective teachers may be unable to distinguish between more and less legitimate claims within a field. Discussions of the syntactic structures of disciplines should of that reason be integrated into teacher education.

Teachers sometimes treat their beliefs as knowledge but beliefs about the subject matter will depend more on evidence that is largely affective or subjective rather than objective. Beliefs are also more disputable than knowledge and are often justified for reasons that don't follow scientific criteria. Prospective teachers' beliefs are related to the content they teach, and these beliefs influence both what they choose to teach and how they teach it. (Grossman et al., 1989)

When teachers hold some of the same naive ideas that the children in their classes hold, and in addition are not aware that those ideas are inaccurate, there are consequences for the quality of both their teaching and their children's learning. Teachers may not recognize children's misconceptions as inaccurate, and may reinforce those ideas (Smith, 1999). Clearly, a strong and useful pedagogical content knowledge cannot be built on a shaky content foundation.

We find that information about what future teachers bring with them to courses about teaching and learning science is critical for their planning and teaching. Much like the children in Carey and Smith's (1993) study scientific knowledge is viewed as emerging in a straightforward way from observations of natural phenomena. Although pre-service teachers use words like "theories" and "hypotheses", their writhing reveal that these are thought to emerge unchallenged from the data as revealed in the natural world, not invented and constructed by humans seeking to make sense and understand events in the natural world. What is striking about pre-service teachers' views is the lack of human participation in what get constructed (Smith, 1999).

Lederman, (1994) found in an investigation of prospective teachers' concerns about teaching a lack or absence of concerns related to subject matter. Prospective teachers' drive to find activities and quick teaching solutions was indicative of their own potentially weak subject matter understanding and their need of classroom management routines prior to being able to attend to student subject matter learning (Hollingsworth, 1989).

For many teachers, the constructivist teaching strategies are very different from anything they themselves have experienced as learners, and they struggle with feelings of anxiety about their own knowledge, when they are forced to teach in an inquiry-based way. Class discussions about what it means to know in science, about teacher roles in the construction of deeper understanding in science, about their own personal histories in knowing science, and about the nature of knowledge construction in scientific communities are then essential activities in teacher education. The construction of knowledge about embedding syntactical aspects of science in daily science lessons is a critically important piece of learning to teach science. (Smith, 1999)

Knowledge about children's ideas can be used when studying curricular representations and materials, and how changes in the design of activities and materials can play syntactical roles in the classroom. Design of ways to represent and consider alternative models and their adequacy also provide opportunities for children to participate in an important syntactical construction in science – the building, testing and revising of models – in addition to making substantive progress in constructing a workable conceptual model. This interweaving of PCK about ways to represent the syntactical nature of scientific investigations in classrooms is an aspect of the construction of knowledge for teaching science in new ways that deserves much more attention (Duschl, 1994).

Teachers' conceptions of the nature of science are essential for their ideas about the teaching and learning of science. If you think that scientific knowledge is self-evident and inherent in the activity you need not know the content deeply nor do you know about children's own theories. But, if you think that humans bring their own prior frameworks to the perception and interpretation of phenomena, then you need different and deeper kinds of knowledge for teaching science. To develop these syntactic aspects of scientific knowledge you need a robust understanding of the scientific explanations and knowledge of how to encourage the interplay of ideas and evidence in a social community to reach agreement about the usefulness of different explanations. In the repertoire of strategies activities that will facilitate this syntactical understanding are to be involved.

Integrated courses for teacher education should focus on teachers' understanding of substantive and syntactical aspects of scientific knowing, as well as connections between that knowledge and the PCK for teaching specific content with children.

Orientations in teacher education

Orientations of science teaching are characterised by the overarching purposes and goals for teaching science at a particular grade level. Pedagogical content knowledge and beliefs in this area serve as a "conceptual map" that guides instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the elevation of student learning (Borko & Putnam, 1996). It is not the use of a particular strategy but the purpose of employing it that distinguishes a teacher's orientation to teaching science.

The orientations are generally organized according to the emphasis of the instruction, from purely process or content to those inquiry-based that emphasize both. Magnusson et al. (1999) distinguishes a series of orientations known from the literature and as examples we here present three of them.

Table 1: Three examples of orientations toward science teaching (Magnusson et al., 1999).

Orientation	Goal of teaching science	Characteristics of instruction
Didactic	Transmits the facts of science	The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science.
Discovery	Provide opportunities for students on their own to discover targeted science concepts.	Student-centred. Students explore the natural world following their own interest and discover patterns of how the world works during their explorations.
Inquiry	Represent science as inquiry.	Investigation – centred. The teacher supports students in defining and investigating problems, drawing conclusions, and assessing the validity of knowledge from their conclusions.

One interesting finding from research is that teachers can hold multiple orientations, including ones such as didactic and discovery that have incompatible goals for teaching science (Smith & Neale, 1989).

Sutton, (1992) emphasize the role of words and language in the teaching and learning process. Expressing a new thought often involves putting words together that would not normally be linked, for example by speaking of a blanket of cloud over the land. In this case it is not an ordinary, literal, use of words because it is figurative quality in them, a metaphorical usage if you like. Human beings figure things out with the aid of figures of speak and it would be absurd to expect pupils to work out for themselves all the specialised ways of speaking which generations of thoughtful human beings have built up. Words steer perception both positively and negatively, and they also influence what people do or do not do as well as what they see or miss seeing. Selecting a metaphor is one of the main tools of innovation in thought. It makes familiar things less taken for granted, and draws our attention to different aspects of the topic. A shift of attention from one shade of meaning to another is what initiates a new understanding. What meaning you get depends on which connections you are attending to. (Sutton, 1992)

It seems increasingly clear that practical experience of itself does not bring about learning until it is animated by ideas, and these ideas are carried in words. At school practical activities can become so prominent that they leave little space for learners to reflect on ideas, or for teachers to organise the means for them to do so.

The words chosen by any speaker or writher help to crystallise his or hers thoughts, and subsequently steer that person's perception. In science it is for "creating and communicating ideas", while in teaching it is for "re-creating ideas" a process that is more than informing the learners. You may use your language in a labelling or a interpretative way and these views of language have very different consequences for teachers. One relies on trying to pass on ready-made meanings directly. The other requires careful exploration of the areas of uncertainty, with the teacher as a sort of coach.

Sutton (1992) means that science itself may be a study of nature, but science lessons should be the study of what people have said and thought about nature. But he also says that it is hard to agree however that in every educational context one is justified in teaching the current specialist meaning as the only possible one.

The teacher preparation program must provide a framework for guiding the prospective teachers' thinking about science teaching. It has to consider teachers' incoming knowledge and beliefs and consistently model an inquiry – based orientation in several ways.

Knowledge of students' understanding

Teacher knowledge of prerequisite knowledge required for students to learn specific concepts includes knowledge of the abilities and skills that students might need. There are several reasons why students find learning difficult in science, and teachers should be knowledgeable about each type of difficulty. For some science topics, learning is difficult because the concepts are very abstract and/or they lack any connection to the students' common experiences. Teachers need to know which topics fall into this category and what aspects of these topics students find most inaccessible (Magnusson et al., 1999).

Effective teachers are aware of students' differing needs and can respond appropriately.

Experienced teachers appear to have developed a conceptual framework in which knowledge and beliefs about science, subject matter, teaching and learning, and students are interrelated in a coherent manner, while their teaching behaviour seems consistent with this framework (Brickhouse, 1990). Prospective teachers are unable to anticipate what students already know, what questions they find difficult, how they might respond to instruction, and what questions they might ask, and encounter difficulties tailoring representations to meet the need of learners (Zembal et al., 1999).

Scientific concepts for which students have misconceptions can be difficult to learn because misconceptions are typically favoured over scientific knowledge because they are sensible and coherent and have utility for the student in everyday life. Although teachers have some knowledge about students' difficulties, they commonly ignore students' misconceptions or struggle for ways to respond to them because of lack of knowledge necessary to help students overcome those difficulties. Besides PCK of materials and activities that interacts with knowledge of children's naive ideas they need teaching strategies that promote alternation in those ideas (Smith, 1999).

Teachers' knowledge about children's ideas in the syntactical area, and about ways to help them construct more sophisticated understandings of the nature of science, is an additional kind of PCK for teaching science. If not everyone in the class agree about the interpretation of evidence, then the teacher needs knowledge of how to encourage the interplay of ideas and evidence in a social community, so that children can listen to each others' ideas and make progress in reaching agreement about the usefulness of different explanations (Driver et al, 1996).

Teacher education programmes should devote more attention to the manner in which teaching implies the transformation of subject matter, and of the critical role that pedagogical content knowledge plays in this transformation (Geddis, 1993). Studies of specific learning difficulties and student conceptions with respect to specific topics are of particular interest, since PCK encompasses understanding of these difficulties of conceptions and focuses teachers' representations and instructional strategies to overcome students' misconceptions (van Driel et al., 1998).

Knowledge of representations and instructional strategies

When teaching science and mathematics you use different kinds of instructional strategies, representations and activities.

Teachers' knowledge of subject-specific strategies is related to the "orientations to teaching science" component of PCK in that there are general approaches to science instruction that are consistent with the goals of particular orientations. One well-known subject–specific strategy is the "learning cycle," a three phase instructional strategy consisting of exploration, term introduction, and concept application. More recently developed strategies have typically added phases designed to support conceptual change strategies, such as eliciting students' pre-instructional conceptions, presenting anomalous data to create cognitive conflict or emphasizing public presentations. (Magnusson et al., 1999)

Representations are about ways to represent specific concepts or principles in order to facilitate student learning. It can be illustrations, examples, models or analogies. Each analogy has conceptual advantages and disadvantages with respect to others. PCK in this area also includes knowledge of the relative strengths and weaknesses of particular representations.

Activities can be used to help students comprehend specific concepts or relationships; for example, problems, demonstrations, simulations, investigations, or experiments. PCK of this type includes teachers' knowledge of the conceptual power of a particular activity. (Magnusson et al., 1999)

An effective teacher must judge whether and when a representation will be useful to support and extend the comprehension of students in a particular teaching situation. Recent research indicates that prospective teachers have difficulty in developing content representations that promote meaningful learning (Borko & Livingstone, 1989; Borko & Putnam, 1996). In order to make representations powerful or more comprehensible to others, one must know learners' existing conceptions and interests related to particular topics, as well as the possible problems they are likely to experience with the content. Representations must be explicitly linked and relationship among concepts must be clear. In science teaching particularly hierarchy of concepts is critical to learning (Novak, 1977). Subject matter knowledge does nor guarantee that it will become transformed into representations that will help students comprehend targeted concepts or that teachers will be able to decide when it is pedagogically best to use particular representations. Teacher's knowledge of strategies for teaching science is often limited (Anderson & Mitchener, 1994) and teachers' abilities to use subject-specific strategies may be dependent upon knowledge from other domains (Smith & Neal, 1989). Experienced teachers seem to know more variations of a demonstration for teaching than novice teachers according to Clermont et al (1994).

The teacher education programme must focus on assisting the pre-service teachers in identifying and implementing appropriate strategies. Comprehensive planning of scientific content for teaching will provide prospective teachers with opportunities to think about issues of content, learners and management and encourage them to develop multiple accurate, appropriate and connected representations. By engaging in interactive teaching, prospective teachers also get the potential to learn more about what students already know, what topics they will find difficult, and what questions they tend to ask. (Zembal et al., 1999)

Knowledge of science curriculum and assessment

Prospective teachers need to develop knowledge of the programs and materials that are relevant to teaching a particular domain of science and specific topics within that domain. They also have to know the goals and objectives for students in the subjects they are teaching, as well as what students have learnt in previous years and what they are expected to learn later (Grossman, 1990).

Knowledge of the major goal of school science, which is that of scientific literacy, is important to assess. Effective teachers should know what aspects of scientific literacy should be assessed in a particular unit and what methods are useable to assess those specific aspects of student learning (Magnusson, 1999). For example students' conceptual understanding may be adequately assessed by written tests whereas their understanding of investigation may require assessment through a laboratory practical examination. Student centred teaching acquire new methods of assessment such as performance-based assessment and portfolios that highlight student generated products.

Teachers engaged in changing their knowledge and practices often realise that traditional assessment activities will not provide them the information about children's thinking that they need to plan, teach and evaluate their lessons (Smith, 1999). Development of new methods or specific instruments or procedures, approaches or activities that can be used to assess important dimensions of scientific learning means that teachers must construct PCK for that. They have to know the advantages and disadvantages associated with employing a particular assessment device or technique and how to inform parents and principals what understanding in science entails, and how children learn.

In the teacher education programme considerable time must be spent on assisting the prospective teachers in developing clear, concise and assessable goals and objectives focused on the learning outcomes of students. Knowledge of orientations of teaching science and of the dimensions of scientific literacy is essential for the planning and preparation of teaching during the period of practice. Integrated coursework and assignment are needed to help prospective teachers to uncover the nature of science and scientists' work and to synthesize their understanding of the various aspects of content representations (Zembal et al, 1999).

Knowledge of context
Personal beliefs and images of teaching and learning that prospective teachers bring with them as they enter teacher education programmes appear to be based primarily on their early experiences as pupils. There are obvious connections between teachers' images of teaching and their classroom behaviour and changes in images can often be associated with changes in behaviour of both teacher and pupils. Teachers need to become skilful in using a range of specific management techniques, and knowledgeable about the circumstances in which a given technique might best be used to promote student learning. The context for practice influences the knowledge about classroom organisation and management that is most relevant for teachers to use.

A problem in the education of teachers has been the issue of how to integrate theoretical knowledge with practical knowledge in order to develop functioning professionals. Experience alone cannot lead to professional development nor can explication of a theoretical principle alone. Practical experience is necessary for the development of classroom experience and can be usefully supplemented by analysis of cases that provide realistic, contextualized exemplars of research-based principles of effective teaching. But it is context-specific pedagogical knowledge that contributes most directly to pedagogical content knowledge (Morine-Dershimer et al, 1999).

Structure of the new curriculum

Progression
In order to get a progression in the development of PCK we intend to begin with elementary subject matter and its relation to students' preconceptions, learning and difficulties. The prospective teachers also have to reflect upon their own conceptions to be aware of the dynamic nature of knowledge and the need of lifelong development of PCK. Then topic-specific strategies and representations, experiments and activities are studied and used in the planning of lessons that are presented, analysed and discussed. After that the prospective teachers will prepare their classroom practice in co-operation with their teacher educators and supervisors. Planning and teaching integrated topics, evaluation and assessment of the pupils' learning and evaluation and reflection of the prospective teachers' own teaching will be highlighted during the period of practice. Problem based studies of integrated subject matter will finish the year.

PCK of science and mathematics, 40 credits
(Detailed plans of objections and content in appendix.)

A1. *Science and technology in children's everyday life, 10 credits*
Chemical, physical and technical phenomena in students' everyday life are studied. Appropriate activities and experiments are carried out, analysed and discussed. Pupils' preconceptions and difficulties are highlighted and ways to explain scientific phenomena and handle pupils' difficulties are discussed. The prospective teachers then plan lessons which are presented, analysed, criticised and discussed in the

group. During this course the prospective teachers have a first contact with their supervisors to get to know their school of practice and their future pupils in order to start their preparing of teaching.

A2. *Science and mathematics in children's everyday life, 10 credits*
Mathematics, suited for the youngest children and ways to handle their preconceptions and difficulties, are studied in a rather concrete manner. Experiments and other kinds of curricular materials are analysed and used in different activities in order to deepen the prospective teachers' understanding of their own and their pupils' conceptions in mathematics.

Different ecosystems in the surroundings are studied and a lot of outdoor activities are practised in order to increase the prospective teachers' and their pupils' interest in and understanding of nature. Knowledge of common plants, birds, fishes and other things that are essential for the teaching at school is focused on.

In a special project patterns and numbers in the nature are studied to get a thematic integration of mathematics and science suited for the youngest children.

Also during this course the prospective teachers are in touch with their supervisors and students at their practice schools.

Comments and directions for the courses A1 and A2
Fundamental subject matter content, relevant for the school, shall be studied and integrated to PCK in order to create a knowledge base suited for science and mathematics teaching at the compulsory school. The prospective teachers' own conceptions and learning shall be brought to light, evaluated and compared to accepted scientific concepts and explanations. Common alternative conceptions shall be discussed and analysed in order to understand pupils' conceptions and difficulties in their learning process. Representations and strategies according to certain orientations and suited for different teaching situations are to be studied and appropriate explanations formulated. Multiple ways of explaining shall be used and analysed in order to highlight the importance of words and language in science and mathematics teaching.

In experiments and other activities for discovering scientific explanations for particular content areas, students can predict what will happen but also to the rest of the group explain why they think so. This will enable them to formulate their thinking in words and consider what they really meant and enable the other students to hear different ways of thinking about the same event. Then they can evaluate those viewpoints in comparison with their own. As a teacher you need to know the students thinking if you want to effectively help them develop scientific and mathematical understanding. Then you need to ask for their explanations, find out a repertoire of questions and activities in order to discover the sequences of ideas that students have in their movement towards more sophisticated scientific theories.

B1. *Science, technology and mathematics in the class-room, 10 credits*
In co-operation with their teachers and supervisors the prospective teachers prepare their teaching to be carried out during their period of practice. Evaluation and analyze of their own teaching as well as evaluation and assessment of the students' knowledge and learning are essential parts of the course. During their six weeks of practice and two weeks of other school-studies the prospective teachers will experience almost all sides of the school context. As an examination of this course they have to write a report for their portfolio about their teaching, analyze and experience of their practice.

At a seminar at the end of the course the prospective teachers, their teacher educators and supervisors discuss and analyse the period of practice.

Comments and directions
Before they start their teaching practice the prospective teachers, in cooperation with their supervisors, choose a relevant domain of subject matter to handle during the period of practice. They then have to study the actual curriculum with goals and objectives, specific curricular programmes and materials but also what students have learned in previous years and what they are expected to learn in later years. In their plans the formulations of goals and objectives, aspects of knowledge to be assessed and methods for that assessment also shall be involved. The cooperation between the university and the schools is essential and of that reason the prospective teachers must be the link with responsibility for relevant information transfer and proposals for questions to be discussed and analysed in the seminaries.
B2. *Man in the universe, 10 credits*
In-depth studies in science and mathematics will complete the year of studies in science and mathematics. The human body and its organs and functions, the theory of heat and an orientation of the theory of relativity will, together with studies in mathematical analyze, give the base for an integrated science project. The prospective teachers have to choose a topic they are interested in and carry out a problem based study of it.

Comments and directions
In this course both substantive and syntactic aspects of science and mathematics shall be treated. The interaction of knowledge from different domains of science and the use of mathematics as a necessary tool in scientific research are to be emphasized in the problem based study.

Acknowledgement
We are grateful to the Swedish Council for the Renewal of Higher Education for its financial support that has made this project possible.

References
Anderson, R. D., Mitchener, C. P. (1994). Research on science teacher education, in D. L. Gabel (ed), *Handbook of research on science teaching and learning*, New York, MacMillan, 3-44.

Borko, H.& Putman, R. T. (1996). Learning to teach, in D. C. Berliner & R. C. Calfee (eds.) *Handbook of Educational Psychology*, New York , MacMillan.

Brickhouse, N.W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41(3), 53-62.*

Carey, S., Smith, C. (1993). On understanding the nature of scientific knowledge, *Educational Psychologist,* 28(3), 235-251.

Clermont, C P., Borko, H. and Krajcik, J. S. (1994). Comparative study of the pedagogical content knowledge of experienced and novice chemical demonstrators, *Journal of Research in Science Teaching, 31(4), 419-441.*

Clermont, C P., Krajcik, J. S. and Borko, H. (1993). The influence of an intensive inserv ice workshop on pedagogical content knowledge growth among novice chemical demonstrators, *Journal of Research in Science Teaching, 30(1), 21-44.*

Driver, R., Leach, J., Millar, R. , Scott, P. (1996). *Young people's images of science.* Philadelphia, Open University Press.

Duschl, R. (1994). Research on the history and philosophy of science. in D. L. Gabel (ed), *Handbook of research on science teaching and learning*, (443-465) New York, MacMillan.

Geddis, A. N. (1993). Transforming subject-matter knowledge: The role of pedagogical content knowledge in learning to reflect on teaching. *International Journal of Science Education, 15, 673-683.*

Gess-Newsome, J. (1999). Pedagogical Content Knowledge: An Introduction and Orientation, in *Gess-Newsome, J., Lederman, N.G.*(eds), *Examining Pedagogical Content Knowledge,* Kluwer Academic Publishers.

Grossman, P.L. (1990). *The making of a teacher: Teacher knowledge and teacher education.* New York, Teachers College Press.

Grossman, P.L., Wilson, S.M., Shulman, L.S. (1989). Teachers of Substance: Subject Matter Knowledge for Teaching, in *Maynard, C. Knowledge base for beginning teacher,* Oxford Pergamon.

Hollingsworth, S. (1989). Prior beliefs and cognitive change in learning to teach. *American Educational Research Journal,* 26(2), 1160-189.

Lederman, N.G., Gess-Newsome, J., & Latz, M. S. (1994). The nature and development of preservice science teachers' conceptions of subject matter and pedagogy. *Journal of Research in Science Teaching, 31(2), 129-146.*

Magnusson, S., Krajck, J., Borko, H. (1999). Nature, Sourses and Development of Pedagogical Content Knowledge for Science Teaching, in *Gess-Newsome, J., Lederman, N.G.*(eds), *Examining Pedagogical Content Knowledge,* Kluwer Academic Publishers.

Morine-Dershimer, G. and Kent, T. (1999). The Complex Nature and Sourses of Teachers' Pedagogical Knowledge, in *Gess-Newsome, J., Lederman, N.G.*(eds), *Examining Pedagogical Content Knowledge,* Kluwer Academic Publishers.

Novak, J. D. (1977). *A theory of education.* New York, Cornell University Press.

Schwab, J. (1978). Education and the structure of the disciplines, in *I. Estbury and N. J. Wilkof (Eds). Science, curriculum and liberal education*. University of Chicago, Chicago, 229-272.

Shulman, L.S. (1986). Those who understand; knowledge growth in teaching, *Educational Researcher,* 15(2), pp. 4-14.

Shulman, L.S. (1987). Knowledge and Teaching: Foundations of the new reform, *Harvard Educational Review,* 57, 1-22.

Smith, D.C. (1999). Changing our Teaching: The Role of Pedagogical Content Knowledge in Elementary Science, in *Gess-Newsome, J., Lederman, N.G.*(eds), *Examining Pedagogical Content Knowledge,* Kluwer Academic Publishers.

Sutton, C. (1992). *Words, Science and Learning*. Philadelphia, Open University Press.

Van Driel. J. H., Verloop. N., de Vos, W. (1998). Developing science teachers' pedagogical knowledge. *Journal of Research in Science Teaching,* New York, John Wiley & Sons, 35, (673-695).

Zembal-Saul, C., Starr, M. L., Krajcik, J. S. (1999). Constructing a framework for elementary science teaching using pedagogical content knowledge. in *Gess-Newsome, J., Lederman, N.G.*(eds), *Examining Pedagogical Content Knowledge,* Kluwer Academic Publishers.

Appendix

A1. Science and technology in children's everyday life, 10 credits

Physics 3 credits, Chemistry 3 credits, Technology 3 credits and School context 1 credit.

Objections: To develop the students'

- knowledge and understanding of fundamental concepts and connections in physics, chemistry and technology
- capability in using an experimental scientific way of working
- knowledge about children's understanding and learning of physical, chemical and technological concepts and connections
- knowledge about girls' and boys' attitudes to science and technology
- knowledge about scientific and technological influences on nature and society
- capability in interpreting the curriculum, formulating goals and objectives, consciously choosing subject matter and methods for assessment
- capability in planning teaching in a 1 – 9 perspective
- capability in planning and carrying out experimental work in the classroom
- capability in handling and using equipment for experimental work in the classroom

Content:

Subject matter

- fundamental theories of science and technology in a historic perspective
- fundamental concepts and connections of relevant scientific and technological domains
- experiment as an origin for the development of knowledge and understanding
- carrying out, working up and presenting of measurements, investigations and constructions
- physical, chemical and technological phenomena in everyday life
- interplay between science, technology and society

PCK

- children's conceptions, conceptual development and understanding of physics, chemistry and technology
- methods and representations to develop children's understanding of scientific and technological concepts and connections
- development of an experimental way of teaching (for children of age 6 - 16 years)
- safety instructions for experimental work
- formulation of goals and objectives and choice of subject matter in agreement with the intentions of the curriculum
- planning of teaching to promote children's learning
- methods of assessment in relation to goals and objectives
- analyse of curricular materials
- detailed planning of lessons (for children of age 9 – 13 years)
- school context studies as preparation of the period of practice

A2. Science and mathematics in children's everyday life, 10 credits

Mathematics 4 credits, Biology 4 credits, Mat/Science 1 credit, School context 1 credit

Objections: To develop the students'

- knowledge and understanding of fundamental concepts and connections in mathematics and biology
- knowledge about nature and environment
- capability in discovering and describe the nature
- familiarity with curricular materials in mathematics and biology
- familiarity with experimental materials in mathematics and biology
- capability in using mathematics as a tool
- knowledge about children's understanding and learning of mathematical and scientific concepts and connections

- capability in interpreting the curriculum, formulating goals and objectives, consciously choosing subject matter and methods for assessment
- capability in planning and carrying out a problem based inquiry teaching in a 1 – 9 perspective
- awareness about teachers' responsibility to develop children's interest and understanding of nature and environment

Content:

Subject matter

Mathematics
- history of mathematics
- children's mathematical thinking
- concepts and conceptions of numbers
- systems of numbers
- Arithmetic
- mental arithmetic
- algorithmic arithmetic
- strategies for problem solving
- elementary geometry
- computer-assisted calculations

Biology
- fundamental ideas and practical ways to discover the nature of the surroundings
- fundamental organism biology
- fundamental knowledge about rock and soil, air and water in a circulation
- common Swedish types of nature
- herbarium
- from geological time to time of the year

Mathematics and biology in cooperation
- numbers and patterns in the nature

PCK
- children's conceptions, conceptual development and understanding of mathematics and biology
- methods and representations to develop children's understanding of biological and mathematical concepts and connections
- development of an experimental way of teaching (for children of age 6 - 16 years)
- development of out door activities
- formulation of goals and objectives and choice of subject matter in agreement with the intentions of the curriculum
- planning of teaching to promote children's learning
- methods of assessment in relation to goals and objectives
- analyse of curricular materials
- detailed planning of lessons (for children of age 9 – 13 years)
- school context studies as preparation of the period of practice

B1. Science, technology and mathematics in the class-room, 10 credits

Mathematics and science 2 credits, School context 2 credits, Practice 6 credits

Objections: To develop the students'

- capability in transforming theoretical knowledge into practical teaching in the classroom
- knowledge of the pupils' conceptions and knowledge of mathematics, science and technology
- capability in adjusting teaching to different pupils' learning

- knowledge of and experience from evaluation and assessment of mathematical, scientific and technological tasks
- knowledge of and experience from cooperation between mathematics, science and technology
- experience from pupils' attitudes to mathematics, science and technology
- experience from teaching mathematics, science and technology in the classroom
- knowledge of and experience from the curriculum and the interpreting of it
- knowledge of and experience from experimental work in the classroom
- knowledge of and experience from outdoors activities
- knowledge of and experience from curricular and experimental materials

Content

- preparing, planning, carrying out and following-up of teaching in mathematics
- preparing, planning, carrying out and following-up of teaching in science and technology
- evaluation and analyse of teaching
- evaluation and assessment of pupils' conceptual development
- organisation of experimental work in the classroom
- organisation of outdoor activities
- evaluation and analyse of curricular and experimental materials

B2. Man in the universe, 10 credits

Mathematics 3 credits, Biology 3 credits, Physics 3 credits Mat and science 1 credit

Objections: To develop the students'

- knowledge of and understanding in relevant scientific concepts and connections for the compulsory school
- knowledge of and understanding in for the compulsory school relevant mathematical concepts and connections
- knowledge of and understanding in the cell, life process and organs and systems of organs of the human body
- capability in using an experimental scientific way of working
- capability in using mathematics as a tool for analyse and problem solving
- knowledge of the gender perspective in mathematics and science
- knowledge of and experience from modern equipment and curricular materials in mathematic and science
- capability in using a scientific overall view
- knowledge of the essence of mathematics and science
- capability in interpreting and analysing the curriculum and consciously choosing ways of teaching in relation to goals and objectives

Content

Mathematics
- algebra
- equations
- functions
- statistics

Biology
- the human body

Physics
- theory of heat
- atom and nuclear physics
- special theory of relativity

Mathematics and science in cooperation

- problem based projects