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Learning to Teach and Teaching to Learn

Primary science student teachers´ complex journey from learners to teachers

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Abstract

This thesis concerns the process of student teachers´ learning to teach primary science and is based on four studies involving primary science student teachers during their teacher education program. The overall question that the thesis intends to investigate is in which ways student teachers' learning about teaching can be illustrated and understood in terms of the critical aspects that are experienced within their teaching and learning practices. The four papers in the thesis purposefully explore student teachers' complex journey from learners to teachers and illustrate the processes of learning to teach by highlighting important aspects within that process. Further to this, the thesis brings into focus the importance of teacher educators' professional knowledge and how that knowledge must impact teacher education practice. The first paper explores four student teachers´ learning to teach in a primary school context. In connection to their teaching they were interviewed as they reflected on the video in order to portray their knowledge needs and how they impacted their abilities to handle classroom situations. The second paper investigates a group of primary science student teachers' experiences from planning, teaching and reflecting on a science lesson with pupils aged between six and eleven in a science learning centre at the university. These student teachers identified critical incidents within their teaching which led them to further portray their own concerns for teaching and their teaching needs. The third paper investigates the joint learning between two primary science student teachers and their mentors during a four week school based practice. Finally the fourth paper investigates primary science student teachers' development of subject matter of, and a positive attitude towards, physics in a specific physics course at the university, and further discusses the importance of subject matter knowledge and self-confidence in teaching primary science. In making explicit student teachers' experiences and concerns for teaching and learning science, the practices and processes highlighted in this thesis help to inform how to involve student teachers in developing a knowledge base for primary science teaching.

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Halmstad in June, 2008

Pernilla Nilsson

List of papers

Paper I

Teaching for understanding - The complex nature of PCK in pre-service teacher education. Nilsson, P. *Accepted in International Journal of Science Education Vol. 30, No. 10, 13 August 2008, pp. 1281–1299*

Paper II

From lesson plan to new comprehension: Exploring student teachers' pedagogical reasoning in learning about teaching. Nilsson, P. *Submitted to European Journal of Teacher Education*

Paper III

Primary science student teachers' and their mentors' joint learning through reflection on their science teaching. Nilsson, P., & Van Driel, J. *Resubmitted to Journal of Science Teacher Education*

Paper IV

How will we understand what we teach? – Primary student teachers´ perceptions of how to develop subject matter knowledge and a positive attitude towards physics. Nilsson, P., & Van Driel, J. *Submitted to International Journal of Science Education*

1. Introduction

1.1. Personal background to the study

This thesis concerns the process of learning to teach primary science and is based on four studies involving primary science student teachers during their teacher education program. The research interest is grounded in my background as a teacher and then further as a teacher educator. In the beginning, it was never my plan to become a science teacher. I actually did not like science lessons in school; in physics in particular. Although I was interested in science, I did not experience science lessons in school as events that stimulated my interest. In the end, it was the low level of interest in science lessons that led me to make the decision to become a science teacher. I wanted to find out ways to help others become interested in what I considered should be the exciting world that science offers.

After completing my teacher education program I taught science in secondary school for several years. In 1996, together with some colleagues, I started a project inspired by the Australian *Project for Enhancing Effective Learning* (PEEL) (Baird & Mitchell, 1986; Baird & Northfield, 1992), in which we evaluated our own teaching. In the project we reflected on our own teaching and encouraged our pupils to take more control or their learning; as well as our teaching. Hence, we used the project to inspire, and further to reflect on questions about how we taught in order to promote pupils' learning, how the pupils described their learning, how we acted as teachers and how we could improve our teaching.

In 2000 when I started to teach student teachers about science teaching at Halmstad University, questions concerning teaching and learning science became even more important to me. As a teacher, teacher educator and researcher, I considered self-reflection to be a catalyst that pushed me along the path towards deeper understandings of teaching and learning. My own and my student teachers' self-reflection then became tools to discover my own role in teaching and learning processes. I was particularly interested in two questions: “what is science teacher knowledge?” and, “how do we prepare student teachers for the complex task of science teaching?”

At the same time I developed a growing interest in primary science, initiated several projects that aimed to stimulate young pupils’ interest in science and started a science learning centre at the university. The science learning centre (which was the research context in paper two) was used for inviting pupils aged 4-11 to come and visit the university to work on science based experiments and problem solving activities and exercises. During these occasions, the student teachers ran the lessons. My experiences with student teachers and pupils at the science learning centre, and further as a facilitator for student teachers during their school based practice, my ideas that teaching about teaching might be grounded into the student teachers’ own experiences were confirmed. Further to this, and as highlighted by Loughran (2006), for teacher educators to know about the relationship between teaching and learning and how that relationship might influence the nature of their pedagogy of teacher education, studies of student teachers’ experiences are crucial.

One of the main problems that I saw within the student teachers’ learning to teach was for them to make a good connection between the academically and practical knowledge. The student teachers often highlighted how they had experienced difficulties in adapting the pedagogical knowledge and subject matter knowledge they had acquired in their academically based coursework to everyday school situations, and further to translate their subject matter knowledge in ways that might be relevant to primary pupils. They often experienced their pre-service courses as being on a too high level resulting in difficulties for them in managing to apply their content knowledge to the different primary teaching situations. Veenman (1984) described aspects of this phenomenon as a “reality shock” or a “praxis conflict” which could force student teachers to recognize, analyze and address their knowledge needs and reconstruct their images of themselves as teachers. For teacher educators to address this “reality shock”, it might be assumed that an insight into the practice of teaching and the contextual factors that influenced practice was needed.

I was interested in studying *how* the conflict in which the student teachers’ often theoretical subject matter knowledge and pedagogical knowledge had to be adapted to primary pupils, influenced their development of a knowledge base needed for teaching. Based on my experiences as a teacher educator I considered that student teachers’ learning to teach and their teaching to learn were strongly connected. Therefore, when I had the opportunity to join the National Graduate School in Science and Technology Education (FontD) at Linköping University in 2003, my research interest became focussed on studying the interaction between student teachers and primary school pupils in the teaching situation, in order to better understand and develop insights into student teachers’ learning to teach through these interactions. Hence, the focus of my research became one designed to illustrate those aspects that needed to be taken into account in the process of developing student teachers’ learning to teach primary science. As such the Ph.D. studies created possibilities for me to further investigate questions which were important not only for me as a curios person, but as a teacher educator in order to shape the learning about teaching that I was attempting to create for my student teachers.

1.2. Background and research aim

The growing focus on learning and teaching about teaching has been highlighted in many ways (Axelsson, 1997; Berry, 2004; Nilsson, 2008). However, much of the research on teacher education programs fail to examine the complex relationship between key learning experiences within teacher education programs and the influence they have on the epistemological beliefs and practices of science student teachers (Anderson & Mitchener, 1994; Cochran-Smith & Zeichner, 2005). In the final chapter of AERA’s panel on research and research report, *Studying Teacher Education*, Cochran-Smith and Zeichner (2005) concluded that teacher education research has paid:

"…little attention to how teachers' knowledge and practices are influenced by what they experience in teacher education programs and even less attention to how teachers are affected over time by their preparation. There is a clear need to look more at how teachers´ knowledge and practices are shaped by their preparations…" (p. 742).

Further to this, there is a concern for more scientific research on teacher education – particularly in relation to how such studies could influence teacher education practices (Cochran-Smith & Zeichner, 2005). Therefore, in order to move beyond notions of teaching as only the delivery of information, there is an urgent need to unpack teaching *and* learning to teach from the point of view of student teachers' experiences in order to create a deeper understanding of *their* needs and *their* concerns.

Several important questions have framed the four papers in this thesis. However, the goal of all four studies is to contribute to an understanding of student teachers' complex journey from learners to teachers. All through the thesis there are different actors that need to be described. The "student teachers" are in their teacher education program, studying to become teachers in maths and science for primary school (in paper one also for secondary school). The "pupils" are school children aged between six and eleven. "Teacher educators" are working at the department of teacher education at the university teaching student teachers in science education or pedagogical knowledge. "Physics teachers" are the science experts at the faculty of physics at the university, teaching student teacher in physics courses. "Mentors" finally are teachers in school who are supervising the student teachers during their school based practice.

The first paper explores four student teachers learning to teach in a primary school context. During one year the student teachers (in pairs) were video-recorded when teaching physics to pupils aged nine to eleven. In connection to their teaching they were interviewed as they reflected on the video in order to portray their knowledge needs and how they impacted their abilities to handle classroom situations. The second paper investigates a group of primary science student teachers' experiences from planning, teaching and reflecting on a science lesson with pupils aged between six and eleven in the science learning centre at the university. These student teachers identified critical incidents within their teaching which led them to further portray their own concerns for teaching and their teaching needs. The third paper investigates the joint learning between two primary science student teachers and their mentors during a four week school based practice. Finally the fourth paper investigates primary science student teachers' development of subject matter of, and a positive attitude towards, physics in a specific physics course at the university, and further discusses the importance of subject matter knowledge and self-confidence in teaching primary science. In making explicit student teachers' experiences and concerns for teaching and learning science, all four papers give insights into student teachers' complex journey from learners to teachers.

By focusing on personal practices and experiences, teacher educators inquiring into their own practice might develop better understanding of the complexities of teaching and learning, both for themselves and for their student teachers (Loughran, 2002). As such, research on teacher education practices offers valuable insights into student teachers' learning needs which, in turn might be helpful for teacher educators in order to improve *their* teaching about teaching. My starting point in this research is my belief that learning always depends on the context, the situations and the social interaction in which it occurs, and that learning to teach is a never ending journey. Thus, what we do in our teacher education programmes, and no matter how well we do them, is only a starting point in preparing teachers to *begin* teaching. As highlighted by (Korthagen, 1993) their needs to be a commitment by teacher educators to help student teachers during their teacher education programme to internalize dispositions and skills in order to study their teaching and to become better at teaching over time. The four papers in this thesis purposefully explore student teachers' complex journeys from learner to teacher and illustrate the processes of learning to teach by highlighting important aspects within that process. Further to this, the thesis brings into focus the importance of teacher educators' professional knowledge and how that knowledge must impact teacher education practice.

Just as Loughran (2006) highlighted, *developing a pedagogy of teacher education* signifies that “the relationship between teaching and learning in the programs and practices of learning and teaching might be purposefully examined, described, articulated, and portrayed in ways that enhance our understanding of this complex interplay” (p. 3).

As a researcher I wanted to study how student teachers experienced their teaching and learning practices in order to illustrate aspects that needed to be taken into account in the process of developing student teachers’ learning to teach primary science. Thus, the student teachers’ own concerns were central in all four studies; even though the third also included their mentors. Therefore the overall question that this research aims to answer is important not only for the research field on science teacher education but also for its implications on the practice of science teacher education:

- In which ways can student teachers’ learning about teaching be illustrated and understood in terms of the critical aspects that are experienced within their teaching and learning practices?

The answers to this question are crucial to the pedagogy of teacher education. Hence, the practices and processes highlighted in this thesis help to inform how to involve student teachers in developing a knowledge base for primary science teaching.

1.3. The importance of teacher education research

It could well be argued that the structure of teacher education may not always offer opportunities for student teachers to transform the knowledge they acquire during course work into the type of knowledge they might need to teach in a [primary] school context. Further to this, student teachers do not always manage to make explicit connections between teachers’ actions and the pedagogical theories that inform practice (Loughran, 2006). Different knowledge bases such as subject matter and pedagogy are often taught separately, thus inadvertently creating a situation in which student teachers themselves need to find ways of transforming their various forms of "knowledge" into useable and meaningful forms within the context of teaching. Hence, there is considerable merit, both in relation to research and practice, in exploring how student teachers through the use of reflection develop and build on different knowledge bases needed for teaching. Clearly, to do so, student teachers need to move beyond their initial needs and concerns so that they might come to recognize and understand the complexity of teaching and see the value in transforming their knowledge into a form that is useable and helpful in shaping their classroom teaching of science.

Further to this, it might well be argued that in Sweden members of the policy-making community embrace a view of teacher knowledge and skill that represents a limited perspective of what teachers should know and be able to do. In their discussions policy makers often emphasize the importance of strong subject matter knowledge, but they only briefly discuss how this subject matter knowledge is to be transformed in a way that promotes pupils' understanding. As a consequence of policy-makers' discussions, teacher education programs as well as school curricula are most likely influenced in a variety of ways. Yet, organizational changes and the complexity of teaching highlights the necessity for more focussed research into the relations between these different elements that constitute teacher knowledge, and how these are developed and integrated during teacher education.

In their review of teacher education research, Anderson and Mitchener (1994) stressed that despite the important role that teacher education programs played for school development, there had been a relatively small amount of research on teacher education. However, in this new century teacher education is beginning to be better valued as an object of academic research. Korthagen, Loughran and Russell (2006) highlighted the importance of research on teacher education. They presented seven principles that they considered important in shaping teacher education programs and practices in ways that might be responsive to the expectations, needs and practices of teacher educators and student teachers. Among those principles "*learning about* *teaching involves continuously conflicting and competing demands"* (p. 1025) is one that particularly stresses the importance of student teachers' learning from experience and building on their professional knowledge in order to shape their thinking about their teaching. "Helping student teachers recognize and respond to competing demands in their learning to teach is one way of helping them to learn in meaningful ways through experience" (p. 1027).

Educational researchers have attempted to document and describe the process of teacher reflection and associated activities, and the relationship between these processes and teacher development (Korthagen, 1985, 1993; Russell & Munby, 1991). Concepts such as "reflective thinking", "action research", "research based" and "inquiry-oriented" teacher education have been embraced by both teacher educators and educational researchers all over the world (Zeichner, 1994). Further to this, Calderhead (1988) highlighted the need for teacher educators to be aware of the complexity of learning to teach in order to consider more critically how tasks in teacher education might lead to knowledge development. Student teachers' awareness of the process of learning to teach might enable them to analyze their own experiences in professional development and to identify areas of knowledge and skills that must be built up (Calderhead, 1988). As highlighted by Zeichner (1994), the research agenda in teacher education should involve research efforts carried out publicly by teacher educators that focus on ways in which particular programme structures and activities, and their own actions, are implicated in the particular kinds of reflective practice that constitutes teacher education:

> "We need research that increases our understanding of the ways in which both individual and social factors affect teachers´ reflections and actions so that we can continually adjust our actions in our programmes in response to these data. These accounts of the reflective practice of student teachers under particular programmatic conditions can also be used as reading material for teacher-education students to help them examine their own patterns of reflection" (p. 21).

Based on the literature reviewed above, it is reasonable to suggest that in order to develop an understanding about student teachers' learning to teach, research in the context of teacher education is crucial. Not only for teacher educators' learning to teach about teaching, but also for the way the structure of teacher education programs might be considered in the future.

1.4. Researching on a researchers' practice

As a researcher you are often confronted with the question of how your research might have an impact on practice. As Russell (2002) highlighted, the theory-practice gap (i.e., that between teaching and research) is just as great in teacher education as in education in general. Hence, it might well be argued that research on a teacher educator's practice (i.e., how to promote student teachers' learning to teach) might shape the understanding of the student teachers with whom he/she works. In the research on science teacher education there are examples of how teacher educators have returned to school teaching in order to learn more about the context in which their student teachers will work (e.g., Pinnegar, 1995; Russell, 1995). Aiming to see how the experiences of daily school teaching in physics affected his thinking about his regular work as a physics teacher educator, Russell (1995) returned to the physics classroom for a semester. By returning to the physics classroom, he recognized anew the significance of personally learning the details of a science textbook's problems, ways of organizing curriculum content and the challenge of learning to use the equipment available in a particular classroom; things that perhaps "slip from the consciousness" when one is a teacher educator rather than classroom teacher.

In this research I have considered a lot of epistemological relationships such as: the need to unpack the experiences of student teachers in a teaching practice within a larger theoretical context (the relationship between theory and research); the value of respect between the researcher and "the researched" in the research process (the relation between research and practice); and, the importance and power of myself as a researcher and therefore the need to articulate and critique my role in the research process (the relationship between theory, research and practice). Therefore, in all four studies of the papers that comprise this thesis I have carefully tried *not* only to describe what I feel as "best practice" of teacher education, but also to focus on how the complex journey from learner to teacher was experienced and illustrated within the student teachers' descriptions of their experiences.

Even though this thesis mainly focuses on student teachers´ learning, as student teacher interact with teacher educators as well as with pupils and mentors in the school context, all participants´ learning from and about each other could be illustrated as in figure 1. Teacher educators learn from and about student teachers through observing how they act and interact with pupils as well as the mentors in the classroom. They also learn through listening to the student teachers' reflections and through taking part in how they experience their teaching and learning. Teacher educators also learn from and about pupils´ and mentors´ ideas and actions as they participate in the classroom context. Furthermore, student teachers learn from and about each other, the teacher educator and the pupils. The different levels of learning are presented in figure 1. Finally, the pupils, as they take part in science teaching, learn from the student teachers. It might also be reasonable to suggest that the pupils might learn something from and about teacher educators as they participate in classroom teaching.

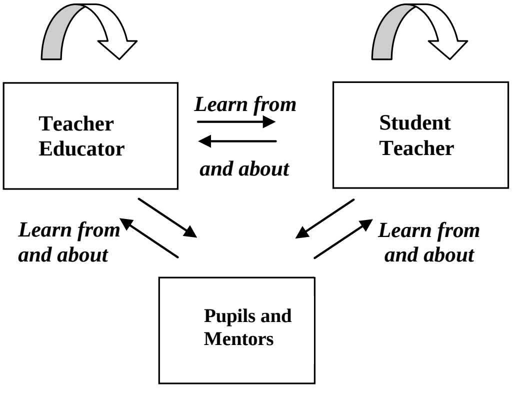

Figure 1. Participants´ learning from and about each other

Loughran (2006) argued that common starting points for self-study inquiries are the questions, problems, tensions and dilemmas that so often cause one to ponder the problematic nature of practice. Therefore, another dimension that can be added to the figure above is that of teacher educators' research on their own practice as something that (hopefully) also helps them to learn about themselves as teacher educators. In the same way, as student teachers are part of research project where they are stimulated to reflect together with mentors and peers, *they* also learn about themselves and *their* knowledge and beliefs.

Kelchtermans and Hamilton (2004) defined self-study as "a mixture of systematic reflection or a form of inquiry that tries to answer relevant questions through a systematic collection of data and their analysis" (p. 786). Loughran (2002) described one characteristic of and purpose in self-study as teacher educators' desire to increase student teachers' learning about teaching and to do so in ways that involve more than teaching as telling. Thus, a renewed focus on the complex nature of teaching about teaching and learning about teaching serves as a catalyst for careful attention to teacher education practices - where the examination of thoughts and actions of practitioners was being conducted by the practitioners themselves (Loughran, 2002).

In his chapter about improving teacher education practices through self-study, Kuzmic (2002) argued that self-study of teacher educators cannot simply be about the lives, practices and history of the teacher educator. It must also understand these in relation to and through the experiences and perspectives of those with whom we are involved (e.g., student teachers).

"We cannot simply objectify the teachers and students that contextualize our lives as teacher educators. Their lives, their concerns, their perspectives and their struggles must find a place in our studies of the self. Thus thinking about self-study as the study of self-in-relation-to-others involves moving beyond recognition of my own complicity in the Othering of teachers in our discourse about teaching, teacher education, and research to a consideration of avenues for change." (p. 233).

Even though through this research I did not set out to study myself, but rather to study and further analyze the experiences, concerns, perspectives and struggles of student teachers, it is obvious that the research results aim to give implications with regard to my own practice as a teacher educator. Hence, it is my intention to transform research knowledge into a form which can readily enter the professional discourse through which student teachers develop a knowledge base needed for teaching. Then clearly, the thesis has that double aim that Bassey (1981) highlighted; to result in generalizations in the form of theories of learning and the knowledgebase needed for teaching, and to contribute to a change in the practice of teacher education. Bassey (2001) further claimed that it is possible to formulate the outcomes of empirical research as fuzzy generalisations (i.e., particular events may lead to particular consequences) and hence be useful to both practitioners and to policy-makers in education. However, as one of the background intentions of this research was to improve *my* [as a researcher *and* teacher educator] understanding of student teachers' professional learning needs in order to find ways of incorporating such knowledge into my teaching about teaching, this research might be placed along the continuum of self-study (Berry, 2004; Kelchtermans & Hamilton, 2004; Loughran & Russell, 2002) and action research (e.g., Axelsson, 1997; Elliot, 1991; Hansson, 2003; Russell, 1995; Stenhouse, 1975; Wennergren, 2007). The usefulness of action research will be further explored in the next section.

1.4.1 Action Research in teaching

In this research on student teachers´ learning to teach, I have used the perspective of action research to guide me in terms of what to pay attention to, how to approach the research problem and how to frame the process of researching practice in order to improve that practice. In the area of teachers' professional development, action research has been widely acknowledged as a way to study teachers as professionals generating practical knowledge (Cochran-Smith & Lytle, 1999; Schön, 1983). Action research can bridge the gap between theory and practice as it helps teachers to understand the purpose of educational research and in turn, inform educational theory about classroom practice (Lytle & Cochran-Smith, 1999). Stenhouse (1975) used the term teacher-as-researcher and argued that in the end it was teachers who would change the world of the school by understanding it. He further argued that being an extended professional involved studying the work of teaching and researching it oneself, not leaving it to others. Elliot (1991) advocated that the fundamental aim of action research was to produce knowledge and theories in order to improve practice. However, action research improves practice by developing the practitioner's capacity for discrimination and judgements in particular complex situations. "It unifies inquiry, the improvement of performance and the development of persons in their professional role." (p. 52). Pedagogical strategies to handle classroom management were, according to Stenhouse (1975), highly context dependant. Thus, it might be possible to generalize strategies from past experiences in several situations but their applicability to future classroom situations must be examined *in situ*.

Further to this, in terms of research into learning strategies, Bassey (2001) stated that researchers and policy-makers would like clear statements, like if we do x in y circumstances, z will be the result. However, as it might be assumed that pedagogical strategies are context dependant, those predictions might be impossible to make. In a similar manner Elliot (1991) argued that generalizations constitute the denial of the individual practitioners. It reinforces the powerlessness of teachers to define what counts as knowledge about their practice. The more the researcher tries to generalize teachers' knowledge, the more threatening it is to teachers because it will contradict their experience of themselves as sources of expert knowledge (Elliot, 1991).

Action research has often been criticized for having problems with objectivity. However, as Stenhouse (1975) advocated this does not need to be a problem:

“The problem of objectivity seems to me as a false one. Any research into classroom must aim to improve teaching. Thus any research must be applied by teachers, so that the most clinically objective research can only feed into practice through an interested actor in the situation. There is no escaping the fact that it is the teacher’s subjective perception which is crucial for practice since he is in a position to control the classroom” (p. 157).

Cochran-Smith (2001) argued the importance of research on how student teachers’ work with professional commitments in order to construct knowledge, open their decision making strategies to critique and further to use the research of others as generative of new questions and strategies. However, as advocated by Cochran-Smith and Lytle (1990), the unique feature of teachers’ questions is that they emanate solely neither from theory nor from practice, but from “critical reflection on the intersection of the two” (p. 6). In this critical reflection, an approach inspired by self-study and/or action research might be useful.

Feldman, Paugh and Mills (2004) discussed the ways in which action research is and is not related to self-study. They concluded that a self-study focuses on the self; it favours the use of life history and narrative forms of inquiry and has been developed within the context of teacher education. Action research is often characterized by the relationship between the outsider as an expert who helps the insider to gain knowledge and other forms of expertise. However, concerning action research it is important to note that while teachers (or teacher educators) are part of the research team, the focus of the inquiry is on the organization and their own practice rather than on the self (Feldman et al., 2004). To conclude this chapter it might be assumed that a teacher educator’s research on student teachers’ learning needs will significantly influence what is known about teaching and learning. As such, it could be assumed that this knowledge might impact on the organizational structure of the teacher education program as well as modifying and transforming the teacher educator’s own beliefs and practice.

2. Theoretical background

2.1. Primary school and teacher education as communities of practice

It might well be argued that teacher education should prepare student teachers to become members in the teachers' community and to participate in educational practices in a competent way. In doing so teacher education can be viewed as involving student teachers in meaningful practices and providing access to resources that enhance meaningful participation in those practices. Therefore, an important theoretical point of departure in this thesis is the premise that [student] teachers learn through practical experiences that are reflected and reasoned and through situated and social interactions with peers and mentors with whom they discuss and get and give feed-back on mutual interests (i.e., teaching and learning science). One approach to think about student teachers' complex journey from learners to teachers is to use the perspective of a community of practice (Wenger, 1998). Lave and Wenger (1991) noted that most of the learning associated with professions comes through the practice situation, and that learning, thinking and knowing take place when people are engaged in activities within communities of practices. Using this framework, we can begin to think about what role participating in primary school teaching might play for student teachers and how teacher education can support student teachers' transition into the community of practice of primary teaching.

Abell (2006) stressed that the situated learning perspective could well be applied to teacher learning.

"The authentic context is the elementary classroom, where students of teaching take part in apprenticeships in which they join, peripherally at first, and more fully as time goes on, the community of practice of teaching…Thus, the situated learning perspective provides theoretical support for the field experiences from which to build models of practice." (p. 77)

In terms of the practice of a primary school community student teachers are often considered as “newcomers” (Wenger, 1998). As highlighted by ten Dam & Blom (2006) “Becoming a more central participant in society is not just a matter of acquiring knowledge and skills; it also implies becoming a member of a community of practice. This requires people to see themselves *as* members, taking responsibility for their own actions (including the use of knowledge and skills) in that position” (p. 651). The title of this thesis “learning to teach and teaching to learn” implies that student teachers' participation in the community of primary school practice is for them both a learning objective and a means for learning.

In this research context, it is further assumed that for meaningful participation in a community, student teachers need to reflect on their initial aims and their interactions with peers, mentors and pupils in order to transform their knowledge of teaching and the content of that teaching through their teaching experiences into pedagogical content knowledge. Within the community, the student teachers act as resources for one another, exchanging information, sharing new ideas and giving each other feed-back. Further to this, the student teachers invite others in the community (e.g., mentors) to participate in their experiences. In such a way, they may well attempt to influence the community and create new knowledge together through that process. When entering the community of primary school practice student teachers bring with them a lot of ideas concerning science content and science teaching. As primary teachers often tend to have limited science knowledge (Appleton, 2003, 2006; Harlen, 1997), working with science student teachers might in turn give them new ideas and thus help the community of primary school practice to further evolve (paper 3).

The research outlined in the four papers points out that participation in a community of practice also requires active involvement in that community. As described by Wenger (1998) participation in this sense is a complex process that combines doing, talking, thinking, feeling and belonging. Thus, it is my belief that participation in a community of practice is an active process where the student teachers (in primary school and in the university course context) through a process of reasoning and action shape each other’s experiences of teaching and learning science. However, student teachers need to be supported in different ways to develop that unique knowledge that enables their competent participation in the practice of teaching. This thesis presents several ways (e.g., stimulated recall sessions and group reflections) of supporting student teachers to actively participate in their learning to teach primary science and simultaneously being data sources for researching those processes and practices. Further to this, participating in the community of practice involves not only acquiring the technical skills needed for teaching but also a personal framework of how to value those skills and how to value oneself as a teacher. As such, it might be assumed that for student teachers to develop their identities as teachers they must engage in the community of practice of primary school. However, as highlighted by Wenger (1998), what is crucial about this kind of engagement as an educational experience is that identity and learning serve each other.

With a focus on early childhood, Fleer (2006) raised the question of “How do early childhood preservice teachers move from being peripheral participants to becoming full members of a science community?” (p. 107). Primary student teachers must cross a border from the community of practice known as “early childhood education” to the community of practice known as “science education” during their science learning. However, if student teachers do not have a framework for the kind of questions and ideas that pupils might have while experiencing and discussing science through objects and experiments, then to become members in the community of practice known as science education will be difficult (Fleer, 2006).

Wenger (1998) argued that participation in a community of practice involved three aspects: engagement; the exploration of new territory; and, commitment. With respect to engagement, the interaction between student teachers and their young pupils in the science learning centre and the classroom (papers 1 & 2 & 3), and with each other during coursework (paper 4) offered opportunities for them to engage in teaching, in discussions of important aspects within their teaching (e.g., pedagogical content knowledge and subject matter knowledge) and hence, in their own learning. The exploration of new territories was highly addressed as the student teachers explored the school context and the new territory of teaching science. Concerning Wenger's (1998) third aspect commitment, the student teachers acknowledged the commitment of their mentors and peers to further consider how different ideas (mostly concerning classroom management) might be used in their own classrooms. Hence, participation in discussions with their peers enabled the student teachers to reflect on their teaching and how they might begin to move into that community. As such, sharing teaching with others might be considered as a means of further developing their teaching.

Cochran-Smith and Lytle (1999) stated that through inquiry "teachers make problematic their own knowledge and practice as well as the knowledge and practice of others" (p. 273). Teachers' professional learning is not only a simple case of adding new information to the existing base of teacher knowledge. Professional learning is an ongoing task in which teachers "need to restructure their knowledge and beliefs, and, on the basis of teaching experiences, integrate their new information in their practical knowledge" (van Driel et al., 2001, p. 140). The fact that people participate in different communities of practices (Wenger, 1998) suggests a mechanism for understanding the interaction and relations among those practices. The goal of teacher education should be to prepare student teachers for the complex task of teaching. Hence, teacher education needs to offer opportunities for student teachers to learn the subject to be taught, as well as ways of presenting this subject in a way that promotes pupils' understanding.

Swedish primary teacher education is mainly built up from three different areas (educational science, subject matter and school based practice). During the school based practice (about 20 weeks during the three and a half years of education) student teachers are expected to synthesize their theoretical knowledge of subject matter and pedagogy with practice in order to develop professionally. The process of synthesizing is, except for the mentoring teachers, most often left to the student teachers themselves.

The focus of this thesis is primary science student teachers, not as individuals but in terms of their development of a knowledge base needed for teaching and the social context in which this development occurs. Therefore, theories of how practice shapes social categories and how knowledge is created within a practice setting (e.g., Lave & Wenger, 1991) have been important for my own understanding of student teachers' learning to teach through teaching. As advocated by Lave and Wenger (1991) knowledge is connected to the situation in which it is practiced.

"Learners inevitably participate in communities of practitioners and that the mastery of knowledge and skill requires newcomers to move forward full participation in the sociocultural practice of a community" (Lave & Wenger, 1991, p.29).

Learning comes from participating in a culture and the community of practice which means *to know,* but also *being together, living meaningfully,* and *develop an identity of profession* (Wenger, 1998). The learning is not only an individual process as the understanding and experiences are in constant interaction. With this framework to structure our thinking, as a community of science teacher educators, we too can be thoughtful and clear about our practice in ways that enable us to educate ourselves and others about science teacher education (Schneider, 2007).

2.2. Science teaching in primary schools

In her review on science teacher knowledge Abell (2007) posed the question: "Do teachers who know more science make better science teachers?"

"If this was true then surely the best science teaching would take place at the university level by teachers who possess Ph.D. in their science field. Yet we know that this is not necessarily so; university science students cite poor teaching as one of the main reasons for dropping out of science majors" (Abell, 2007, p. 1105).

She goes on to pose a question about what science teachers should know in addition to science knowledge and how they come to know it. During the last two decades, Swedish primary teachers have been confronted with new challenges concerning science teaching. In Sweden as in several other countries, primary teachers are faced with teaching several subjects and coping with shifting roles in different subject matter contexts. Primary teachers therefore need to have content knowledge in all theses different subject areas. As many science teachers have had negative experiences in science during their own schooling they have tended to avoid science in their higher education studies (Skamp, 1997). As such, it might well be argued that the tendency for primary school teachers to avoid science has resulted in their limited science content knowledge and low confidence in teaching science.

Similar to other countries, Sweden has experienced government interventions leading to reforms of teacher education programs, school curricula, national tests and other criteria for measuring the quality of schools and teaching. Also teachers' attitudes and beliefs have been found to be a major influence in the implementation of the science curriculum (see for example, van Driel, Beijaard & Verloop, 2001). In 1994 the national school curricula changed to present goals that pupils should achieve in every subject. In the context of primary science teaching, the new curricula stipulated a large amount of goals to be reached in physics, chemistry, biology and technology. These new curricula raised discussion about primary teachers' scientific knowledge, attitudes towards and confidence in teaching science. Another important issue for primary science is that in Sweden, like in several other countries, evaluations of secondary pupils' scientific knowledge through such things as TIMSS and PISA have had a great impact on policymakers' requirements for science teaching in primary and secondary schools. Most primary teachers are struggling to survive the demands that the national primary science curricula requires. However, they need to develop subject matter knowledge as well as a positive attitude towards and self-confidence in teaching science if the educational needs of their pupils are to be met.

Research on primary student teachers' learning to teach (Appleton, 2006; Nilsson, 2008; Skamp, 1997), have emphasized the importance of primary science student teachers' framing and reframing of their practice (Schön, 1983, 1987) in order to gain new insights into *what* and *how* they perform teaching. An important task of the primary science teacher is not only to help pupils to acquire content knowledge of science but also to inspire them and stimulate their interest. In order to teach science in ways that might promote pupils' understandings as well as their interests, Shulman (1986, 1987) claimed that teachers need pedagogical content knowledge (PCK), a special kind of knowledge that teachers have about how to teach particular content to particular pupils. However, as highlighted by Appleton (2006), "Given that many elementary school teachers have a limited science content knowledge and therefore limited science PCK, how do such teachers manage to teach science at all?" (p. 32). One way for teachers to manage science teaching in primary schools is to develop a working set of science PCK through the use of science "activities that work" (Appleton, 2002). These are activities with which teachers feel comfortable, that they have taught before and that have fairly predictable outcomes in providing pupils with science knowledge (Appleton, 2003).

Even though there are primary teachers who teach science effectively and regularly, we know from research that primary and elementary school teachers have limited science knowledge (Appleton, 2003, 2006; Harlen, 1997; Harlen & Holroyd, 1997). They tend to lack confidence in the adequacy of their own science knowledge and in their ability to do and learn science for themselves (Appleton, 2006). Thus, the level of complexity of one's subject matter knowledge structure is a critical factor in how easily knowledge structures influence classroom practice and embodies the *content* fundamental to the development of PCK.

Harlen and Holroyd (1997) designed a study of primary teachers' subject matter knowledge to evaluate their knowledge about different concepts. Three groups of correct and incorrect conceptions were defined: (i) concepts already understood by the teachers; (ii) concepts of which understanding developed during the interviews; and, (iii) concepts that were less commonly understood. It was also determined that a lack of everyday language of physics was at the source of teachers' inaccuracies. Osborne & Simon (1996) claimed that primary teachers' lack of ability, confidence and enthusiasm for the science subject resulted in the use of less stimulating methods and that teachers did not respond effectively to pupils' questions. Further to this, teachers who have little subject matter knowledge have limited options "…especially if they lack confidence to choose activities that work from science topics about which they know little, or to acquire new science content knowledge for themselves" (Appleton, 2006, p. 42).

Palmer (2001) emphasized that subject matter knowledge and science pedagogical content knowledge increased teachers' confidence in primary science teaching. Harlen (1997) found that teachers' depth of subject matter knowledge could affect the ability of the teacher to ask appropriate and meaningful questions. Planning often became limited and defined by what the teacher knew rather than an exchange of knowledge between the learner and the teacher (Harlen, 1997). This was confirmed by Carlsen (1991), who found that the less the teacher knows, the more often discussions with the pupils appeared to be dominated by the teacher. Further to this, the less competent the teachers were, the more difficult it was for them to follow the child's lead and to explore their ideas (Carlsen, 1991).

To plan learning experiences that engage and challenge pupils' thinking of science, teachers need to develop knowledge of science teaching, pupils, pupils' learning and the curriculum that can be translated into meaningful practice. As pre-service teacher education is often teachers' first opportunity to reflect on the actual *use* of their subject matter knowledge, the importance of such opportunities can not be over-emphasized (Lederman & Gess-Newsome, 1999). Teachers need to understand the structure and nature of their discipline, have skills in selecting and translating essential content into learning activities, and recognize and highlight the applications of the field to the lives of their pupils (Gess-Newsome, 1999).

The relationship between teachers' attitudes and behaviour was highlighted by Bandura (1977, 1981) who proposed that every person has a sense of self-efficacy which was connected to his/her beliefs in their own abilities to perform an activity.

Applying Bandura's theories of self-efficacy to teaching science would suggest that teachers' behaviour with regard to teaching would be determined by their own confidence in their ability to teach science. It can be seen that teachers have a high self-efficacy while teaching a well known subject, but low self-efficacy while teaching science. In the context of science teacher education an important issue might then be to cultivate a more positive self-efficacy by developing student teachers' confidence to teach science effectively. In so doing, science teacher educators must empower student teachers to see themselves as learners of both science and science teaching, and also involve them in constructing their own science understandings (Koch, 2006).

2.3. Experience and reflection in teacher education

In order to learn from practical experiences it is reasonable to suggest that experiences must be reflected and reasoned upon with peers as well as with mentors. Therefore an ultimate goal of teacher education might be to develop student teachers' competence to frame and reframe problems, to reason about solutions according to their interpretations of the situations and to formulate ideas for their future actions. Teachers in general, but perhaps science teachers in particular have to face new challenges all the time in both *what* they teach (because the scientific knowledge in the society is constantly developing), *how* they teach it (experimental methods can be unpredictable) and *why* (school science has for some pupils' and primary teachers a low priority). In his pedagogical credo (1897) Dewey described beliefs that served as the starting point for a discussion about education:

”I believe that one of the greatest difficulties in the present teaching of science is that the material is presented in purely objective form, or is treated as a new peculiar kind of experience which the child can add to that which he has already had. In reality, science is of value because it gives the ability to interpret and control the experience already had. It should be introduced, not as so much new subject-matter, but as showing the factors already involved in previous experience and as furnishing tools by which that experience can be more easily and effectively regulated.“ (Dewey, 1897)

Reflecting on one's own teaching practice can be an intense but also a useful process (Loughran, 2002). Therefore, it seems reasonable to suggest that by encouraging primary science student teachers to reflect on their own teaching they may well develop deeper insights into their understandings of science teaching and learning. As such, learning from experience is crucial in shaping the development of a knowledge base for teaching. Therefore, familiar approaches to teacher research draw on notions of reflective practice (Dewey, 1933; Schön, 1983, 1987). Dewey (1938/1997) drew attention to the need for experience in the development of thoughtful student teachers. Hence, to reflect on and share the learning through experience is critical to the development of student teachers´ learning to teach.

Dewey (1916/1966) described learning as taking place in different situations and not limited to one special situation. A person experiences a situation, successful or unsuccessful, reflects on it and develops a method to handle the situation. We do something, fail, do something new and continue until we finally do something that works and then we use the successful method in the next situation. In the same way people learn from successes. We do something successful which we bring into the next situation. However, we do not always manage to see *how* actions and consequences are linked together. But if we know on *what* the results depend, we might also examine what conditions are needed for a good result. Further to this, if we know what conditions are required we can also work in order to satisfy the conditions needed. In such ways, the quality of an experience is changed and we can call it a reflective experience (Dewey, 1916/1966). As Dewey (1933) advocated, "reflective thinking" involves among other things a state of doubt, hesitation and perplexity, and also an act of searching and inquiring to find materials that will resolve the doubts. Hence, the process of reflection is an active one, whereby knowledge is created through experience.

It has been argued (above) that student teachers learn from their experiences. However, it is reasonable to suggest that an individual's experience has an authority of its own that should be contrasted with other people's experiences as well as educational arguments (Munby & Russell, 1994). Building on Schön's (1983) work on developing knowledge-in-action, Munby and Russell (1994) used the term "authority of experience" to inform oneself about the acquisition and the use of professional knowledge. Accordingly, one way of helping student teachers begin to see into the complexities of teaching and learning in new ways is to foster a sense of trust in their "authority of experience".

If we transfer this reasoning to the context of science teacher education we can say that student teachers must be given opportunities and possibilities to recognize and further reflect on failures (e.g., failed experiments and demonstrations) and successes in order to acquire a higher metacognitive level, develop an authority of their own experiences and a knowledge base for teaching. Therefore, recognizing that which is a problem (or a success) in practice becomes important starting points for the reflective process. To achieve such a metacognitive perspective, student teachers must not only recognize situations within their teaching but also come to a deeper understanding of their own behavior and the theories and ideas that shape their action strategies. However, it is reasonable to suggest that student teachers' experiences during practicum placements can be viewed as data from which they might become more informed about their own development as teachers. Having the capacity to reflect on your own practice paves the way to making decisions about the nature of professional learning that also will improve your practice. Hence reflection and analysis might help to identify a person's needs, both in improving what you already know and in recognizing what you do not know (Bishop & Denley, 2007).

Several studies (e.g., Calderhead, 1988, Korthagen, 1993; Korthagen & Kessels, 1999; Loughran, 2002; Munby & Russell, 1993; Shulman, 1987) emphasize that teachers should become reflective practitioners in order to develop expertise in their practice. Indeed the practice of *reflection* has become a cornerstone in many teacher education programs. Korthagen (1993) defined reflection as people's learning to subject their personal beliefs of teaching and learning to a critical analysis, and thus take more responsibility for their actions. According to Boyd and Fales (1983), reflection was a process of creating and clarifying the meaning of experience in relation to self, but also of self in relation to the external world.

Schön (1983) used the terms “reflection-in-action” and “reflection on action” to refer to a set of skills. According to Schön (1983), “Reflection-in-action” was used to explain how practitioners develop a certain kind of thinking that was incorporated in action which makes them more able to accomplish their work. Hence, the “thinking” was incorporated in practitioners’ doing, in their actual, situated, action. However, according to van Manen (1995) classroom work assumes action over which there is no time to reflect. Theoretical knowledge, knowledge of a special subject and teaching skills are not always directly applicable in the actual classroom of chaos and unexpected events. Other forms of skilfulness are required to master these situations. Van Manen (1995) used the term “Pedagogical tact” to describe this practical and experience-based competence that he recognized as a position between theory and practice and between thinking and action.

Many studies support the view that student teachers should become reflective practitioners in order to develop their practice beyond the technical alone (Calderhead, 1988, Korthagen, 1993; Loughran, 2002). However, as highlighted by Van Manen (1995), studies into reflection illustrate that beginning teachers often experience tensions between their beliefs and their actions in the practice of teaching. Therefore, it could well be argued that the earlier student teachers become aware of their teaching needs the earlier they may begin to systematically study their practice. For that reason, preparation of teachers who are reflective about their practice continues to be a dominant theme in teacher education. As teacher educators, we want our student teachers to *recognize* and see what factors matters in a classroom (Nilsson, 2008). For that reason, as highlighted in the four papers in this thesis, for student teachers there is a clear need to make explicit their own concerns in order to choose how they might act on them. Therefore “effective reflection” (Loughran, 2002) might help student teachers to recognize aspects within their teaching which they might not have been able to see otherwise.

2.4. Teacher knowledge

In their review of the cognitive and psychological nature of teacher thinking and decision making Clark and Peterson (1986) argued that teachers' actions were directed by their thought processes and that there was an interactive relationship between teachers´ thoughts and actions. In other words, teachers´ actions were guided by their thoughts which, in turn, were influenced by their actions. Thus, conceptions of teaching influenced teachers´ classroom behaviour and their teaching activities influenced their conceptions of teaching. In their review, Clark and Peterson (1986) highlighted that a major goal of research on teachers´ thought processes was to increase understandings of the "how and why" of the process of teaching (i.e., what does it look like and why does it look that way?)

Clark and Peterson (1986) developed a model consisting of two domains that were important in the process of teaching, teachers´ thought processes and teachers´ actions and their observable effects. They suggested that teachers´ thought processes occurred "inside teachers´ heads" and are unobservable; in contrast to this, teachers´ actions are observable and are more easily subjected to empirical research methods. Therefore, bearing in mind the interactive relationship between teachers´ thoughts and actions, through acts of teaching that are *reasoned* and *reflected* upon collaboratively with others (e.g., mentors and peers); student teachers' learning about teaching might be able to be mapped and therefore illustrated in new ways to others. Thus, it is important to do empirical research on what student teachers do but also do research on stimulating their reasoning about how they interact with pupils, mentors and peers in order to say something about how their interactions influence thinking about, as well as the act of teaching.

It could well be argued that student teachers are often interested in knowledge that is practical and can be applied in the classroom. It is also a common assumption that student teachers do not always manage to make explicit connections between teachers' actions and the pedagogical theories that inform practice. Theoretical knowledge is not experienced as immediately useful for student teachers in addressing their problems in practice (Loughran, 2006). Student teachers' problems of connecting theoretical knowledge with the practical knowledge could well be illustrated by a "zipper metaphor" (Kelchtermans & Ballet, 2006), where one side of the zipper illustrates theory and the other side illustrates practice. When closing the zipper it can get stuck, which then forces the person to stop and to reflect on what is wrong. If we transfer this to the practice of teaching, student teachers might experience critical incidents (Tripp, 1993) when they try to connect theory to practice within their teaching. Those incidents force them to conceptualize aspects of their practice that they need to address in order to meet their explicated pedagogical concerns. However, approaching the development of knowledge as learning through experience can help to bridge theory and practice (i.e., close the zipper) in a meaningful way.

An ongoing concern in the learning to teach literature is the need to help student teachers move beyond notions of teaching as the "delivery of information", and begin to critically reflect on, and seek to actively develop, stronger links between their teaching, their pupils' learning and, importantly, their own learning to teach (see for example, Berry, 2004; Chin, 1997; Feiman-Nemser, 2001). Kagan (1992) noted that:

"university courses fail to provide novices with adequate procedural knowledge of classrooms, adequate knowledge of pupils or the extended practical needed to acquire that knowledge, or a realistic view of teaching it in its full classroom/school context" (Kagan, 1992, p. 162).

As the literature makes clear, this is a difficult transition for student teachers because their "apprenticeship of observation" (Lortie, 1975) has created a strong sense of experiencing teaching as telling. Fuller and her colleagues (Fuller, 1969; Fuller & Bown, 1975) performed innovative research (at that time) in developing a picture of the first year of a teacher's career. In her work she integrated the existing research on teachers' concerns over time with research on the perceived problems of student teachers, experienced teachers and beginning teachers in order to find "teaching phases" helpful for teacher educators in developing more appropriate training programmes. Fuller & Bown (1975) posited three distinguishable stages of concerns that were characteristic of teachers. The first stage involved *survival concerns* which were concerns about one's adequacy and survival as a teacher, class control, being liked by pupils and being evaluated. The second stage included *teaching situation concerns* which were about limitations and frustrations in the teaching situation such as methods and materials. The third stage reflected on *concerns about pupils, their learning and their social and emotional needs*. However, the experience of becoming a teacher involved coping with all three stages.

Teacher knowledge literature refers to a host of words describing the knowledge base needed for teaching. These could be craft knowledge, tacit knowledge, situated knowledge, professional knowledge, personal knowledge, pedagogical content knowledge and pedagogical context knowledge. These names might not necessarily refer to different types of knowledge, but could be, in some way, like names we give to people. Hence it is important not to argue about *what* we call the certain knowledge, but instead focus on the actual meaning of the concept and what the name stands for. A person is given a first name, a nickname and sometimes also one or two additional names. Even if the context of use might be different, the names always refer to the same person.

In transferring this discussion to Shulman's (1986, 1987) notion of pedagogical content knowledge (PCK), the concept might be helpful in our thinking about what student teachers need to learn, and what science teacher education needs to offer in order to "effectively" instruct them. The concept of PCK can be helpful in our continuing discussions about what is teacher knowledge and how is it developed. It can be used as a theoretical as well as a methodological framework to structure research on teachers' knowledge and how it is developed. However, if Shulman wanted to initiate a world wide discussion about the nature and definitions of the knowledgebase needed for teaching, he was surely successful. "Shulman certainly started a ball rolling when he initially (and quite loosely) formulated the concept of

PCK. It may continue to be one of those unfolding stories where the journey is more important than the destination (Bishop & Denley, 2007, p. 204)." Therefore, in the next section the concept of PCK will be carefully discussed.

2.4.1. The notion of Pedagogical Content Knowledge

The question of what makes PCK important and how it might be recognized and developed, initiates an important discussion about what we actually know of science teachers' professional abilities and the tacit nature of teaching practice. However, does the construct of PCK help or constrain our endeavour of educating teachers? Regardless of what concept of teacher knowledge that best explains the knowledge teachers need to possess, the concept of PCK as a construct and a model has proven to be fruitful. In this thesis the concept of PCK is used as the knowledge a teacher needs to construct and implement science learning experiences for pupils. It is a dynamic form of knowledge that is constantly expanding and being transformed from other forms of teacher knowledge, and through the experiences of planning, conducting and reflecting on science teaching and learning. As highlighted by Bishop and Denley (2007), if we could define the knowledgebase needed for teaching, it might assist new teachers' structure their professional learning and know better how to acquire it.

In his overview of the research on teachers' knowledge, Shulman (1986) stressed that research about the content of teaching in relation to the act of teaching was missed during the last century. Shulman further stressed that these questions were important in the context of teacher education as well as for experienced teachers. Shulman (1986) raised the question about the knowledge bases needed for teaching and whether or not teachers possess them. How should the teacher use the content to build on analogies, metaphors, examples and demonstrations in order to promote pupils' understanding?

In his first PCK paper, Shulman (1986) distinguished between three categories of knowledge: Subject matter content knowledge, pedagogical content knowledge and curricular content knowledge. Subject matter content knowledge was important as the teacher must not only be knowledgeable of his/her subject but also possess other qualities related to the subject such as the subject matter structure, which content was central and which was on the periphery and in what way the subject could be questioned and criticized. Curricular knowledge was central for the knowledgebase for teaching as the teacher should be aware of the specific curricular goals but also materials and different ways of presenting a teaching content. In the same way as a doctor needs to know more than one way to treat different categories of infectious diseases, a teacher needs to know more than one way to handle a teaching situation. Pedagogical Content Knowledge (PCK) was defined by Shulman as a knowledge that focused on the teaching of the subject: "the most useful forms of representation, the most powerful analogies, illustrations, examples, explanations, and demonstrations" (p. 9). PCK also includes knowledge about what makes the subject difficult or easy to understand (i.e., conceptions and misconceptions about the subject). As such, PCK is a specific form of knowledge for teaching which refers to the transformation of subject matter knowledge. As highlighted by Shulman (1986), teachers need a special type of knowledge to structure the content of their lessons and then to use specific representations or analogies in order to promote pupils' understandings.

In his second (PCK) paper, Shulman (1987) elaborated his definition of teaching knowledge to comprise seven different categories: "*content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, knowledge of educational ends, purposes,* and *values and their philosophical and historical grounds*." Among those seven, Shulman considered that PCK was of special interest as: "…it identifies the distinctive body of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented and adopted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). Hence PCK is strongly related to the teaching of a specific subject. As such, Shulman saw PCK as content knowledge transformed by the teacher into a form that makes it understandable to pupils. So, science PCK then included knowledge of the content to be taught and how to promote pupils' learning. Shulman went on to include in PCK "an understanding of what makes the learning of specific concepts easy or difficult: the conceptions and preconceptions that pupils at different ages and backgrounds bring with them to the learning" (p. 9). So, it might well be argued that PCK includes a knowledge of pupils and their pre and misconceptions; hence a pupil-centred pedagogy.

Shulman (1987) then went further to describe the process of *pedagogical reasoning and action* in which the knowledge base for teaching is developed and used. Pedagogical reasoning though is not as simple as just thinking about teaching. According to Shulman (1987) and Wilson et al. (1987), pedagogical reasoning comprises a cyclic process. Teaching begins with comprehension whereby teachers first need to understand the subject matter themselves and also understand how the ideas within their discipline are interrelated and connected. Comprehension also comprises an understanding of the aims and purposes of teaching. Following comprehension is transformation in which teachers transform their content knowledge into forms that are pedagogically powerful and adaptable so that the content might be understood despite the diversity of pupils' learning styles. Instruction follows transformation and involves such things as organizing and managing the classroom, explaining, interacting effectively with pupils, discussing and providing effective teaching. Evaluation follows instruction and that includes checking for pupils' understanding and misunderstanding, as well as the formal testing and evaluation that teachers do to provide feedback and grades. Interestingly, evaluation is also directed at one's own teaching, at the lesson and the materials employed in those activities. In that sense it leads directly to reflection. Reflection is what a teacher does when she/he looks back at the teaching and learning that has occurred, reconstructs, re-enacts and recaptures the events, the emotions and the accomplishments. Finally then, the process of pedagogical reasoning cycles back to influence new comprehension as a result of the learning achieved through experience. Therefore, through acts of teaching that are reasoned, new comprehension of the content, pupils and the processes of pedagogy emerge.

The exact relationship between PCK and the model of pedagogical reasoning and action was not clearly expressed by Shulman (1987) but could be inferred in general terms from the descriptions above. Knowledge suggests something static, and reasoning and action implies a dynamic state where knowledge is being tested and refined and a new understanding is generated. Shulman (1987) stressed that teacher education should provide student teachers with the understandings and the performance abilities they would need for their pedagogical reasoning. A natural question might then be: "Is it possible to provide the student teachers with "critical incidents" (Tripp, 1993) which might help them recognize and identify important issues for this development to occur?" Thus, teacher educators need to engage student teachers in activities that create experiences and stimulate reflection.

2.4.2. Interpretations and explorations of the concept of PCK

Shulman´s ideas of PCK have created a considerable interest for research as well as for the practice of teaching. Various scholars have further developed conceptualizations of PCK (e.g., Appleton, 2002; Gess-Newsome, 1999; Loughran, Mulhall & Berry, 2004, 2006; Magnusson, Krajcik & Borko, 1999; Van Driel, Verloop & de Vos, 1998) as an academic construct representing specialist knowledge of practice. As such, PCK has become a way of understanding the complex relationship between teaching and content through the use of specific teaching approaches and is developed through an integrated process rooted in classroom practice (Van Driel et al., 1998). On the international arena the concept has been accepted in the educational research.

"PCK has become an accepted academic construct that represents an intriguing idea. It is an idea rooted in the beliefs that teaching requires considerably more than delivering subject content to students…PCK is the knowledge that teachers develop over time, and through experience, about how to teach a particular content in particular ways in order to enhance students' learning" (Loughran et al., 2006, p. 9).

Despite that, a lot of researchers still aim to identify the concept. However, it is important to consider that it is not the *concept* itself that needs to be discussed but the knowledge of what the concept actually stands for. Bishop and Denley (2007) highlighted that rather than seeing PCK as a different "type" of knowledge, it could be viewed as a sophisticated process of combining knowledge bases together for particular contexts in relation to classes, topics or other factors. Therefore, instead of arguing about the definition of PCK it is important to focus on the processes that are involved in the development of PCK.

With a focus on science education, Gess-Newsome and Lederman (1999) made the first systematic effort to synthesize the research on PCK and the model from which the concept originated. Their aim was to find implications for the concept in research as well as in practice. They raised questions about the common conceptions of PCK: "What research exists to support PCK and the related constructs of teacher subject matter knowledge and pedagogical knowledge? How have researchers used both PCK and its related constructs to develop lines of research on teacher thinking and learning? and, How have visions of PCK been applied to teacher preparation program development and evaluation?" (Gess-Newsome, 1999, p. 4)

In her introductory chapter Gess-Newsome (1999) described two extreme models of teacher knowledge, the *Integrative* and the *Transformative* model. In the Integrative model, PCK does not exist as a domain of knowledge and teacher knowledge is explained as an intersection of subject matter, pedagogy and context. When teaching in the classroom, knowledge from all the three domains is integrated to create effective learning opportunities. According to Gess-Newsome (1999), an expert teacher, then, is one who has well-organized individual knowledge bases that are easily accessed into and could be flexibly drawn upon during the act of teaching. An advantage (in terms of considering the development of practice) of an integrative model is that domains of knowledge can be developed independently and be integrated at a later stage. Therefore, later on, knowledge of specific teaching can be deconstructed to its original area, to be deepened or reorganized later (Gess-Newsome, 1999). A potential danger with the Integrative model is that teachers may never see the importance of such knowledge integration.

The Transformative model represents a synthesis of all knowledge needed in order to be an effective teacher. Knowledge of subject matter, pedagogy and context, whether developed separately or integrated are transformed into a new form of knowledge that is more powerful than its constituents parts. Thus, the three knowledge bases become more useful when transformed into PCK. An expert teacher, then, has well formed PCK for the topics commonly taught. The danger with this extreme is that it could be seen as objectifying teaching and so student teachers' decision making skills, personal growth and creativity might be overlooked.

Grossman (1990) conceptualized PCK as consisting of four components: knowledge of subject matter; knowledge of pupils' conceptions and difficulties; knowledge of curriculum; and, knowledge of instructional strategies. PCK is then developed as a result of a knowledge transformation, but unlike the transformative model of Gess-Newsome (1999) there is a reciprocal relationship between the domains. Magnusson et al. (1999) suggested that teachers hold different views and beliefs about teaching and learning. They identified orientations (e.g. academic rigor, conceptual change, activity driven, discovery, project based science, inquiry and guided inquiry) that influenced teachers´ choices of aspects such as learning goals, learning experiences and teaching strategies. Magnusson et al. (1999) further developed a model of PCK for science teaching through which the "overarching knowledge for teaching" consisted of five different components: (1) orientations toward teaching science, (2) knowledge of science curricula, (3) knowledge of pupils' understanding of science, (4) knowledge of assessment in science, and (5) knowledge of subject-specific and topic-specific strategies. As the components interact in complex ways effective teachers need to develop expertise in all aspects of pedagogical content knowledge, and with respect to all topics they teach.

Magnusson et al. (1999) used the term orientation to represent a general way of viewing or conceptualizing science teaching. Knowledge and beliefs in this area guide a teacher's instructional decisions about the organization of activities, the content of pupils' assignments, the use of textbooks and curricular materials and the evaluation of pupils' learning. They further stressed that the development of PCK is a complex process which is determined by the content to be taught, the context in which the content is taught and the way the teacher reflects on his/her teaching experiences. If the student teachers are to be successful in creating classroom environments in which subject matter and pedagogy are integrated in a way that promotes pupils' learning, they must experience such learning environments themselves (Magnusson et al., 1999).

To describe the relationship between PCK and the other six categories of knowledge that Shulman (1987) proposed, Bishop and Denley (2007) used a metaphor of a spinning top with coloured segments (knowledge categories) that were discrete and readily distinguished from each other when the top was still, but which merged to form a different colour when spun. The new colour was generated from the component colours but was different from them. As Shulman (1987) defined PCK as an amalgam of knowledge, the "spinning top metaphor" illustrated PCK as a dynamic construct which is not amenable to static representation and can only be "seen" in action (Bishop & Denley, 2007). The focus on the thinking behind the selection and application of knowledge instead of the individual bits of knowledge themselves is somehow close to the notion of "pedagogical content knowing PCKg" developed by Cochran, De Ruiter & King (1993). Hence, PCK is to be considered as a dynamic knowledge generated in practice through the capability of the teacher to be able to combine or blend the individual knowledge bases together (Bishop & Denley, 2007).

Even if there is a large amount of research on teacher education and the expertise of teaching, the Swedish research on science teacher education has been relatively limited. Lager-Nyqvist (2003) followed student teachers during their teacher education and then as beginning teachers in order to make them express their ideas about the teacher's role, the teaching methods and content and also about the practical training during their teacher education. Lager-Nyqvist (2003) concluded that teacher education programs had obviously *not* changed the student teachers' ideas and neither had it offered the student teachers opportunities to develop their PCK according to their own goals and the school curricula. Ekborg (2002) studied how student teachers developed relevant knowledge in science for teaching about the environment, and how the student teachers' reasoning about complex scientific relationships developed during teacher education. Further to this Zetterqvist (2003) explored the complexity of teacher education when investigating biology student teachers learning to teach evolutionary biology.

Across the views of PCK described above, what kind of PCK is relevant from the point of view of science teacher education? Giving support to the ideas of considering PCK as a dynamic knowledge generated in practice through the capability of the teacher to combine the individual knowledge bases together, there is commonality in terms of three well recognized knowledge bases: Pedagogical Knowledge (PK); Subject Matter Knowledge (SMK); and, Contextual Knowledge (CK). However, their specific definitions and their relation to PCK must be explored. Pedagogical Knowledge (PK) consists of general elements regarding teaching, classroom organization and management, instructional models and strategies, classroom communication, lesson plan development and implementation, and student evaluation. Hence, Pedagogical Knowledge concerns the processes and practices or methods of teaching and learning and how it encompasses overall educational purposes, values and aims. As such, pedagogical knowledge requires an understanding of cognitive, social and developmental theories of learning and how they apply to pupils in their classroom (Mishra & Koehler, 2006). Contextual Knowledge (CK) is strongly connected to PK and represents knowledge of school departments, traditions, behavior of pupils, the climate in the classroom, the relationship between individuals, and the context in which teaching takes place. The contextual knowledge therefore also includes an understanding about social and special need education knowledge and theories and, their applicability in the classroom.

Finally, a teacher also needs to understand the central concepts and structures of the discipline(s) in order to create learning experiences that make the content meaningful to all pupils. Therefore Subject Matter Knowledge (SMK) refers to a teacher's quantity, quality and organisation of information, conceptualisations and underlying constructs in a given field of science (Zeidler, 2002). As mentioned in earlier research (Abell, 2007; Gess-Newsome, 1999), lack of SMK makes it difficult for student teachers to relate phenomena to everyday situations, but subject matter alone is not sufficient. Different knowledge needs to be transformed.

Thus, from the point of view of this thesis, PCK is considered as a dynamic construct. A complex entity built on definable knowledge bases, where the components of knowledge function as parts of a whole and a lack of coherence between components can be problematic in developing and using PCK. As the components interact in a highly complex way (e.g., in the spinning top), it is important to understand not only the particular components of PCK, but also to understand *how* they interact and how their interaction influences thinking about, as well as the act of teaching.

Loughran et al. (2006) emphasized the importance of helping student teachers as well as experienced teachers in understanding their practice in order to increase their understanding of their tacit knowledge, and hence, influence their foundation of PCK. Thus, to *recognize* different aspects in a teaching situation and also to *interpret* the impact of those aspects becomes important for the development of a knowledge base needed for teaching (i.e., PCK).

2.5. Experts and novices in different contexts

In the context of teacher education research, the discussion of teaching expertise and how it develops are important issues. Further to this, as student teachers (in this research context) spend about twenty weeks in the school context working together with experienced teachers, the relationship between the novice (student teacher) and the expert (mentor) must be investigated and further explored (paper 3). As we know from research (e.g., Berliner, 2004; Björklund, 2008) expert teachers operate in a qualitative different way than novices. Based on comparative studies on expert and novice teachers, Dreyfus (2004)[1] and Berliner (1988) introduced a five stage model of teacher development: *novice* (class-room teaching is rational and relatively inflexible); *advanced beginner* (the teacher develops strategic knowledge and classroom experiences and the contexts of problems begin to guide the teacher's behaviour); *competent* (the teacher makes conscious choices about actions, knows the nature of timing and what is and is not important); *proficient* (intuition and know-how begin to guide performance and a holistic recognition among contexts is acquired. The teacher can predict events); and, finally *expert* (intuitive grasp of situations, teaching performance is fluid as the teacher no longer consciously chooses the focuses of attention).

As advocated by Kagan (1992) the stages in Berliner's model were distinguished from each other concerning how a teacher monitors the events in the classroom and the degree of consciousness involved in the teaching. Kagan (1992) described the behavioural and conceptual development of beginning and novice teachers in five components: an increase in metacognition (novices become more aware of what they know about pupils and classrooms and how their knowledge and beliefs are changing); the acquisition of knowledge about pupils (knowledge of pupils are used to modify the novices image of self as a teacher); a shift in attention (the attentions shifts from self to the instruction and learning of pupils); the development of standard procedures (novices develop standardized routines that integrate instruction and management); and, finally, growth in problem solving skills (thinking associated with classroom problem solving grows more differentiated, multidimensional and context-specific).

Kagan's (1992) model accounted for the shift in a novice's concerns from self to the pupil suggesting that the novice's initial focus constituted necessary and valuable

[1] A summary of the author's fivestage model of adult skill acquisition, developed in collaboration with Hubert L. Dreyfus. An earlier version of this article appeared in chapter 1 of Mind Over Machine: The Power of Human Intuition and Expertise in the Era of the Computer (1986, Free Press, New York)

behaviour. Before the initial self-image was adapted and reconstructed, the novice could not progress. Thus, the development of expertise was identified through a move towards an unconscious recognition of common patterns, flexible automated routines (Kagan, 1992).

As Berliner (1988) argued, there might be too little in the minds of student teachers about what actions that might be realistic, relevant and appropriate in a teaching situation. As mentioned by Bransford, Brown and Cocking (2000), the idea that experts recognize features and patterns that are not noticed by novices is potentially important for improving teaching. One dimension of acquiring greater competence in teaching then appears to be the increased ability to “unpack the practice” and learning how to see and recognize important aspects needed for teaching (Nilsson, 2008). Further to this, if you can get expert science teachers to articulate what they know about teaching, student teachers might be able to use these insights in their learning to teach (i.e., teaching needs in paper 1 & 2). Research on expertise suggests the importance of providing pupils with learning experiences that specifically enhance their abilities to recognize meaningful patterns of information. Referring to Bransford et al. (2000) a person who has developed expertise in a particular area of knowledge is able to think effectively about problems in that area. Hence, an expert can notice the features and meaningful patterns of information acquired from nature through observations or experiments.

Even though the idea of expertise might apply to all sorts of fields, in connection to expert teachers’ and student teachers’ (novices) recognition of important aspects of their PCK, it could be possible to make a comparison with the expertise of wine tasting. Hughson and Boakes (2002) emphasized that experts and novices used different criteria to categorise domain-specific problems, in that novices use simplistic surface features whereas experts use underlying principles. Comparing this to the context of teaching, expert teachers might have more descriptive abilities with respect to describing a teaching situation and hence to recognize important aspects needed for teaching. Further to this, Parr, White, & Heatherbell (2004) explored the nature of wine expertise through investigating the *recognition* of wine-relevant odours as a function of wine expertise. However, surprisingly they found that the recognition memory for domain-specific aromatic compounds by wine experts was, despite their odour-identification skills, similar to those of novices. One possible reason for this result might be the fact that many wine-relevant odours are also everyday odours and for people who enjoy cooking and gardening it could be well known odours.

Let us return to the recognition of aspects needed for teaching. Every person who has been in the school context, either as a pupil, parent or teacher might recognize factors that identify "best teaching". But this must not necessarily mean that they would be able to *teach* in the "best way". General factors such as "knowing the subject and to like children" might be recognized by all conceivable persons, but more underlying principles (Hughson & Boakes, 2002) connected to PCK might be more difficult to recognize. The expert wine taster has experienced hundreds of different wines and has learnt to interpret and analyze the factors that make the wine good or bad. As a result of long experience the expert has learnt to recognize different nuances, differentiate between two wines and even put words on and identify the difference. If we again transfer this reasoning to student teachers learning to teach, their ability to recognize their teaching needs (i.e., elements that constitute the knowledge base of teaching) is crucial if they are to develop those elements and transform them into pedagogical content knowledge.

Van Driel et al. (1998) emphasized the importance of classroom experience in order to develop PCK. Hence, this would suggest that student teachers with very brief teaching experience would lack PCK. Using the metaphor of the wine taster, the novice does not have enough knowledge about what characterizes a good wine. To appreciate a Chateaux Muzar you must learn to recognize its good characteristics. To be able to develop your PCK you must learn to recognize elements that build it up. With this background PCK might be considered as a useful concept in order to analyze, describe and characterize the complex phenomena called science teaching. Although student teachers (novices) can not always identify their own needs it might be reasonable to suggest that one important factor for enhancing a development of PCK is through *recognizing* and *confronting* the difficulties and dilemmas of practice. Therefore, they must be offered adequate tools to manage this recognition. The methods used in the papers in this thesis (stimulated-recall, story-lines, interviews) but also reflective portfolios (Nilsson, 2008) are all tools to stimulate student teachers; "seeing" into their own practice.

There is a need to capture the different elements needed for teaching and to find ways of how student teachers might "spin the top" (Bishop & Denley, 2007) during teacher education. "The best strategy might be to combine a theoretical and empirical analysis to generate as complete a picture of PCK as possible and yet keep it grounded in classroom practice" (Marks, 1990, p. 11). Also, a proper understanding of the sophisticated development of PCK with student teachers may support teacher educators' thinking about what student teachers need to learn, and what science teacher education needs to offer in order to effectively instruct them.

3. The research process

3.1. Framing the four studies

During the years I have worked with the four papers my intentions have been to find issues that student teachers themselves identified as important for their learning to teach. Hence there are several issues in the papers that tie them together. The first issue is that all four studies concern student teachers' *own* expressed experiences and concerns for learning and teaching science that ground the basis for empirical data. The second issue concerns the methods as all four papers deal with reflection on teaching and learning. The third issue is the concept of PCK, which is discussed in all four papers. As such all four studies in the thesis were concerned with my own efforts as a teacher educator researcher to investigate how different knowledge bases needed for teaching were perceived by student teachers through reflection on their teaching experiences (paper 1-3). Further to this, as the first three papers all highlighted the importance of a positive attitude towards science and an appropriate subject matter knowledge, the fourth paper then focused on *how* different factors, such as practical experiments and following group discussions, contributed to primary student teachers' development of subject matter knowledge in combination with a more positive attitude towards physics. Thus, the studies together aimed to contribute to the knowledge of ways student teachers' learning about teaching can be portrayed and understood and the critical aspects that student teachers experience within their teaching and learning practices.

The data that this thesis builds on comes from four different studies, all four on primary science student teachers at the department of teacher education. In the first study, four student teachers in the final year of a four and a half year pre-service program (Maths/Science for primary and secondary school) participated in a specific research project: *Journey of knowledge in physics*. This project aimed to inspire primary school pupils' interest in science and technology, and to provide student teachers with possibilities to regularly teach and learn science in a school setting. Over the course of a year, the four student teachers taught physics once a week. They worked in pairs in their teaching assignments. As the project was not a regular part of their pre-service training, they planned the lessons themselves, with no input from the teacher educators. During the year, each pair was video recorded by the researcher for six lessons. In two different stimulated recall interviews, the researcher discussed three of the six video recorded lessons with the student teacher pairs (i.e., Interview 1: Lessons 1, 2, 3; Interview 2: Lessons 4, 5, 6). The data obtained from the stimulated recall sessions were analysed in order to produce a description of what the student teachers raised through their reflections. Hence, the aim of the recall approach was to present a detailed description of the student teachers' experiences with the goal of seeking to better understand the complex notion of their professional learning.

The context of the second study was a primary science teacher method course in a Science Learning Centre located at the university. The Science Learning Centre is a specific room, specially designed to stimulate pupils' scientific learning. It is also used in primary science teacher education methods courses as it offers many opportunities to prepare and evaluate different experiments, but it also provides an opportunity to experience science teaching in an out of school environment. The Science Learning Centre was initiated in 2002 and has since been used in teacher training and in science teacher professional development courses. In addition it also offers an opportunity for pupils aged four to eleven to attend the centre to experience science lessons as an additional component to regular schooling. The lessons normally include different experiments aimed to encourage the pupils to experience science as something interesting. The pupils are stimulated to work in a problem-based manner, putting forward hypotheses, documenting their observations and discussing their results.

The student teachers who participated in the second study were studying in a three-and-a-half year's educational program, where one year was dedicated to teaching math and science to pupils aged up to eleven. At the time of the study they were in their third term having a task to plan and conduct a lesson with a group of pupils in the Science Learning Centre. The student teachers worked in pairs or trios and the themes of the lessons concerned mostly different scientific phenomena related to an everyday context.

The data collected consisted of (A) questions to the student teachers before the lesson, (B) questions to the pupils and (C) written answers of the questionnaire at the seminar and (D) tape recordings of group discussions concerning the answers of the questions of A, B and C and the student teachers' spontaneous reflections in the seminar. As the questions before the lesson and the questions to the pupils were all sources of written data, and were only shared by the student teachers who taught the lesson, the intention of conducting a group seminar after the lesson was to place the reflection in a social context to stimulate student teachers' pedagogical reasoning.

The third study concerns what and how primary science student teachers and their mentors learn from planning and reflecting together on each other's science lessons for pupils aged 7 to 9. It examined what two mentoring primary teachers and two primary science student teachers learned from their common experiences while planning, carrying out, and reflecting on different science teaching activities during a four-week school practicum. The student teachers had had training in scientific knowledge, but only brief experiences of teaching. The mentors were well experienced in the pedagogy of teaching and mentoring, but did not feel confident about their science content knowledge and the teaching of science. During the four weeks, two lessons of each of the student teachers and mentors were video recorded. The student teachers and the mentors, working in pairs, reflected on each video-recorded lesson in a stimulated recall session. During their reflections, the student teachers and the mentors expressed several examples of their joint learning experiences throughout the process of working, observing, and reflecting together.

The research context of the fourth study was an eight-week physics course in the second term of a three-and-a-half-year pre-service primary teacher programme where one year was dedicated for science (c.f. study two and three). The study aimed to investigate *how* different factors, such as practical experiments and subsequent group discussions, contributed to primary student teachers' development of subject matter knowledge in combination with a more positive attitude towards physics. During an eight-week course, 40 primary science student teachers worked in groups of 13-14 in experimental workshops on practical experiments and problem-solving skills in physics. The experiments had an open design and were built on everyday phenomena (such as investigating acceleration and forces in an elevator). The student teachers were video recorded in order to follow their activities and discussions during the experiments. In connection with every workshop, the student teachers participated in a seminar; they watched the video-recording in order to reflect on how they communicated their conceptions in their group. After the eight weeks of coursework a questionnaire including a storyline was used to elicit the student teachers' perceptions of their development of subject matter knowledge from the beginning to the end of the course. Finally, five participants were interviewed after the course.

3.2. Research questions

In the introduction chapter the overall research question was presented as:

- In which ways can student teachers' learning about teaching be portrayed and understood in terms of the critical aspects that are experienced within their teaching and learning practices?

In the four papers, several specific research questions have been posited in order to more fully outline the research. These are summarized below:

Paper 1:

- Which elements of PCK were perceived by the student teachers in their reflections about teaching pupils aged nine to eleven?

Paper 2:

- What critical incidents influence student teachers' pedagogical reasoning in learning to teach?
- What teaching concerns do student teachers recognize in their own practice as they reflect on their learning to teach?
- What teaching needs do the student teachers formulate in order to manage their identified teaching concerns?

Paper 3:

- What knowledge do student teachers develop from their mentors while jointly planning and reflecting on each other's science lessons?
- What knowledge do mentors develop from student teachers while jointly planning and reflecting on each other's science lessons?
- What knowledge do student teachers and mentors develop from pupils while jointly planning and reflecting on each other's science lessons?

Paper 4:

- What factors do primary science student teachers consider important for their development of subject matter knowledge in physics?
- How do these factors contribute to the student teachers´ development of SMK and a positive attitude towards physics?

The answers to all these questions offer meaningful insights into student teachers' learning to teach and hence their complex journey from learners to teachers.

4. Methodological framework and research design

Underpinning the qualitative methods (Cohen, Manion & Morrison, 2007) used in the four studies was the assumption that issues concerning teaching and learning do not happen in a social or a cultural vacuum but in communities of practices. From the perspective of Vygotsky (1934/1986) and Wenger (1999) the sociocultural nature of learning suggests that work with other individuals is a critical component of the learning processes. Further on, as highlighted by Dewey (1933) learning is highly dependant on the activities in which a person participates and how the person reflects on his/her experiences. Hence, when student teachers (and mentors) are encouraged to reflect on and discuss their teaching and learning experiences with peers, they might [or not] conceptualize important aspects related to their development of a knowledge base needed for teaching.

As this research focuses on individual actors (or groups of actors) attempting to understand their perceptions of events, the research has been inspired by a case study approach (Cohen et al., 2007). Case studies observe effects in real contexts and recognize that the context is an important determinant of both causes and effects. Therefore, in this thesis student teachers and mentors within the context of teacher education and primary school practice are considered as cases.

According to Cohen et al. (2007) the context is unique and dynamic; hence case studies investigate and report the complex dynamic and unfolding interactions of events, human relationship and other factors in a unique instance. Case studies are concerned with a rich and vivid description of events relevant to the case and strive to illustrate what it is like to be in a particular situation and to catch “thick descriptions” (Geertz, 1973) of participants´ lived experiences of, thoughts about and feelings for a situation. Further to this, case studies look at cases or phenomena in real life context usually employing many different types of data (Cohen et al., 2007). In the context of this research, I have been aware of the ways in which my perception and background as a teacher educator shaped the research and how the cases were designed and data was collected. However, my awareness of the effects that my background could have on the research process has stimulated my reflexivity (i.e. recognition of how previous experiences might impact on the interest of and the implementation of the examination).

In the four papers, several methods of *data collection* have been used to illustrate student teachers’ learning about teaching in terms of the critical aspects that were experienced within their teaching and learning practices. In three papers (papers one, three and four) stimulated recall interviews were used to stimulate student teachers´ (and mentors´) reflections on their teaching. In paper two both written reflections and group interviews were used. Except for the stimulated recall sessions, in paper four storyline questionnaires and semi-structured interviews were also used. Thus, even though the four studies all attempted to answer the same overall research question, each paper highlights different aspects concerning student teachers´ teaching and learning science. Therefore, appropriate methods to collect data were selected in order to respond to the different research questions that were posed in the four papers and to collect reliable data appropriate to the specific nature of each study comprising the specific paper.

According to Cohen et al. (2007) triangular techniques in the social sciences attempts to map out or explain more fully the richness and complexity of human behaviour. In this thesis triangulation is not used in all four individual papers, but taking into account that the four papers all refer to the overall research question, the concept of triangulation is worth to be mentioned. As research methods are like a filter through which the environment is selectively experienced, they are never neutral in representing the world of experience. Exclusive reliance on one method might then distort a researcher's picture of the particular aspect being investigated. However, what is important concerning the different methods of data collection in this thesis is that they are all designed in order to seek to illustrate the nature of participants' learning to teach (student teachers and mentors) and may be described as interpretive or subjective. Therefore, the purpose of the different methods used in this thesis is designed to illustrate, analyse and interpret situations through accessible accounts (e.g., student teachers´ reasoning and reflections) to give a richer and deeper picture of each particular case. Case studies are also used to capture the complexity of behaviour and to contribute to action and intervention (Cohen et al., 2007). The "cases" in the four studies consisted of student teachers and mentors (paper three).

Finally the methods for analysing the collected data in all four papers were based on qualitative methods. According to Cohen et al. (2007) qualitative data analysis involves organizing, accounting for and explaining the data: "in short, making sense of data in terms of the participants´ definitions of the situation, noting patterns, themes, categories and regularities." (p. 461).

In qualitative analysis, the researcher decides which data are to be selected for description and further investigation. This usually involves some combination of deductive and inductive analysis. While initial categorizations are shaped by the pre-constituted research questions, the researcher should remain open to inducing new meanings from the data available. Thus, analysis becomes a reflective interaction between the researcher and the de-contextualized data that are already interpretations of a social encounter. The researcher brings to the data his or her preconceptions, interests, background and agenda. Therefore, in conducting qualitative data analysis, a great deal of self awareness and caution must be exercised by the researcher (Cohen et al., 2007).

In the four papers that comprise this thesis, content analysis (Miles & Huberman, 1994) has been used in order to reveal the different ways in which student teachers (and their mentors) perceived their teaching and learning. The aim of the content analysis was to identify, and further analyse transcriptions within the data which appeared to be central in the participants' reflections. According to Cohen et al. (2007) content analysis examines any form of communicative material and may be applied to substantive problems at the intersection of culture, social structure and social interaction. Hence, content analysis can be undertaken with any written material and is often used to analyze large amounts of text data. Content analysis involves coding, categorizing (relating meaningful categories into which words, phrases and sentences can be placed), comparing categories and making links between them and finally drawing conclusions from the text data (Cohen et al., 2007).

4.1. Data collection methods used in the studies

As described above, in order to capture the complexity of student teachers' learning to teach and thereby make explicit the factors that student teachers described as important within their journey from learners to teachers, different methods were used. Stimulated recall interviews were used in study one and three, written questionnaires were used in study two and four, group interviews were used in study two and finally storylines and semi-structured individual interviews were used in study four.

4.1.1. The stimulated recall interview

Video-recording of the teaching in the classroom was used to stimulate the student teachers' (and mentors' in paper three) reflections on their teaching and to remind the participants of their own activities and thinking. This "stimulated recall approach" has been used in several studies to facilitate student teachers' and teachers' learning from their experiences where respondents comment on their work (Alexandersson, 1994; Brown & Harris, 1994; Calderhead, 1981; Clark & Peterson, 1986; Davis, 2003; Freitas et al., 2004; Mead & McMeniman, 1992; Stough, 2001). Thus, the teacher is enabled to recollect and report on his or her thoughts and decisions during the teaching episode. The teacher's reports and comments about thoughts and decisions while teaching are audio-taped, transcribed and subjected to content analysis (Clark & Peterson, 1986).

Jensen (2002) described stimulated recall as an enlightening and detailed method to elicit information about student teachers' teaching. During the stimulated recall interviews in study one and three the participants studied the video tape together with the researcher and were asked to stop the tape and comment on "special events" in the teaching situations. The notion of a special event was explained to the participants before the session to be something that made them reflect, e.g., connected to their activity and their interaction with the children during their teaching; e.g., how they experienced the lesson, their feelings, attitudes and intentions. In paper four, stimulated recall was used to stimulate student teachers' reflections on their activities and discussions during the experimental workshops. In all three studies, the stimulated recall sessions were designed to explore what student teachers *themselves* perceived as important components for their own knowledge base for teaching and how these aspects of teaching were transformed during classroom practice. In so doing, it was anticipated that responses would offer insights into the development (or otherwise) of participants' PCK.

4.1.2. The story-line method

In study four the story-line method was used as one way of collecting data. The story-line method focuses on teachers' stories, i.e., the way teachers make sense of, evaluate and clarify their own experiences and events in practice (Beijaard, Van Driel & Verloop, 1999). Beijaard et al. (1999) tried to determine how and under what conditions this method could be used to best elicit teachers' practical knowledge about relevant current and prior experiences and events in their professional lives. The method was also used by Gergen (1988) to evaluate college students' feelings of general well-being and by Henze (2006) to view the development of teachers' knowledge as teachers' learning in a workplace. As mentioned by Beijaard et al. (1999), a story-line can be qualified as progressive (from a negative to a positive evaluation), stable or regressive (from a positive to a negative evaluation). Further to this, not only the direction of the story-line but also the incline contains information of a certain experience or event.

The story-line method was used to "trigger" the student teachers' reflections in order to uncover events during the eight weeks that pertained to their development of subject matter knowledge. The student teachers were asked to grade (on a five point scale where 1 was low and 5 was high) how their subject matter knowledge in physics developed every week. Hence, the story-line represented student teachers' evaluation of their level of knowledge of physics on the vertical line of the graph on a 5-point scale, which was plotted in time on a horizontal time scale during eight weeks.

According to Gergen (1988) the information collected with the story-line method can sometimes be too general or fail to do justice to all details. Therefore, a questionnaire was also used where all the student teachers were asked to clarify their story-lines and describe events that influenced high and low points in the graph in order to "unpack" factors that they perceived as important for their attitudes towards and learning of physics.

4.1.3. Semi-structured interviews

Semi-structured interviews (Cohen et al., 2000; Kvale, 1996) were used in the fourth study in order to get a deeper insight into the student teachers' ideas and perceptions. According to Kvale (1996) semi-structured interviews are conducted with a quite open framework which allows a two-way communication between the researcher and the researched. Hence, semi-structured interviews can be used both to give and receive information.

In study four the interviews were based on the written questionnaire with the storyline. Unlike the questionnaire where detailed questions were formulated, in the semi-structured interviews firstly the student teachers were questioned about their experiences of the course. Then they were asked to carefully comment on their story-lines and to explain what had caused the high and low points, the directions or changes of directions and the directions of inclines. Finally they were asked to further elaborate their answers in the questionnaire. Significant for the semi-structured interviews were that several questions were created during the interview, which allowed both the researcher and the student teacher the flexibility to probe for details or discuss issues.

4.2. Validity of the study

In qualitative research the relationship between the researcher and the respondent(s) might be considered as an ethical concern. How can my desire as a researcher to receive feedback in the interviews be reconciled with the need to avoid influencing the informants' stories?

Cohen et al. (2007) highlighted that validity might be addressed through the honesty, depth, richness and scope of the data achieved, the participants approached, the extent of triangulation and the objectivity of the researcher. In qualitative data the subjectivity of the respondents, their opinions, attitudes and perspectives together contribute to the results of the study. However, data are socially situated and the natural setting and the context become important. In naturalistic research (as opposed to positivistic), the researcher is a part of the researched world and as we live in an already interpreted world a double 'hermeneutic exercise' is necessary to understand others' understandings of the world (Cohen et al., 2007). There should also be holism in the research and the researcher, rather than a research tool, constitutes the key instrument of research. Cohen et al. (2007) further argued that in naturalistic research the data are descriptive and there is a concern for process rather than simply with outcomes and data are analyzed inductively rather than using a priori categories. Data are also presented in terms of the respondents rather than researchers, hence, seeing and reporting the situation should be through the eyes of participants. As stressed by Cohen et al. (2007) we as researchers are part of the world that we are researching and we cannot be completely objective about that.

One important aspect of validity concerns *reflexivity*. Reflexivity is, according to Cohen et al. (2007), the recognition that researchers are a part of the social world that they are researching and that this social world is an already interpreted world by the actors undermining the notions of objective reality. Researchers bring their own biographies to the research situation and participants behave in particular ways in their presence. As stressed by Cohen et al. (2007) reflexivity suggests that the researcher should acknowledge their own selves in the research seeking to understand their part in or influence on the research. Rather than trying to eliminate the researcher's effect, which is impossible as the researcher is a part of the world they are researching, they should hold themselves up to the light. As such, "highly reflexive researchers will be acutely aware of the ways in which their selectivity, perception, background and inductive processes and paradigms shape the research" (Cohen et al., 2007, p.172).

The notion of reflexivity is also central to action research because the researchers are a part of the social world they are studying. However, what has been required in the notion of reflexivity is a self conscious awareness of the effects that the participants-as-practitioners-and researchers are having on the research process and how their values, attitudes, perceptions, opinions, actions, feelings etc. are feeding into the situation being studied. Finally reflexivity is when the researcher during the research process tries to see things from different perspectives. Reflexivity concerns the researcher's own interest for the problem and own connection to the research project and how previous experiences might impact on the interest of and the implementation of the examination. Further to this, reflexivity could be about how to approach the empirical data and how the researcher comments and reflects on the relation between the interviewer and the respondent.

Kvale (1997) outlines different kinds of validity of which I see at least three of them as central to this work, *pragmatic validity, communicative validity and inter-subjective validity*. First, pragmatic validity includes the extent to which the research outcomes are considered as useful. Pragmatic validity is based on observations and interpretations, and is joined with a commitment to actions related to the interpretations. Hence, the validity of the knowledge is tested through the way it actually is brought into action in order to change practice (Kvale, 1997). As such, if the action results in the desired result, the knowledge is valid. Thus, justification of knowledge is replaced by application, with a pragmatic concept of validity. Action research is one of those approaches that emphasize actions that in turn can change practice. In action research, researchers and respondents develop a common knowledge about a social situation and then apply this knowledge through new actions in this situation, whereas the validity of the knowledge is then tested in practice. The research outlined in this thesis seeks to bring together student teachers' actions and reflections. Hence, central to these studies is the importance of the relationship between theory and practice and how to interpret practical knowledge that comes out of student teachers' [and their mentors'] experiences. Therefore, the research process in itself may generate important insights into student teachers' learning to teach, as well as a frame to interpret these insights.

Second, Kvale (1997) outlines a communicative approach to validity. This approach is built on the notion that an interpretive process can never be objective, but is always inter-subjective and the data is interpreted as experienced by the researcher (Kvale, 1997). However, communicative validity concerns the way the researcher argues for the relevance of his/her interpretations. Communicative validity is related to the inter-subjective validity which concerns the way the research has been reviewed and criticized during the process and also the academic status of the persons who have discussed the work. In a research context where data can be interpreted in many different ways, the researcher's ability to argue convincingly for the interpretation that they have proposed must be stressed. The researcher does not search for the 'right' interpretation, but for an interpretation that is defensible, in a context where the researcher is selecting from a range of possible interpretations (Kvale, 1997). On this basis, both the research methods and final interpretation need to be regarded as appropriate by the relevant research community. Participation in research seminars, conference presentations and peer reviewed journals provide a source of feedback from a communicative approach to validity. Communicative validity is developing through communication and both the researcher and the respondents learn and change through the dialogue. However, the researcher's interpretation is not objective as the researcher searches for underlying, often implicit meanings in the data. Further, as an individual's experience of a phenomenon is often dependent on the context, there is no expectation that the respondent would experience exactly the same situation the next time.

This research is supported by *pragmatic validity* as well as *communicative and inter-subjective validity*. Concerning pragmatic validity, the methods used, the research design and the results imply that the research actually has a practical application and is useful to school teaching as well as science teacher education. Concerning *communicative validity* the research studies have all been discussed in research seminars and conferences. All four papers have been discussed by reviewers as well as research colleagues who have promoted important feed-back in developing the ideas. Finally concerning *inter-subjective validity,* all four papers have been reviewed and criticized by peer-reviewers as well as research colleagues during the process. Hence, different researchers have discussed the work and have participated in the process of analyzing and discussing the data.

Cochran-Smith and Lytle (1990) advocated that cooperative research provided valuable insights into the relationship between theory and practice but it often constructs and predetermines the respondents' and the researcher's roles in the research process. Hence, the teacher's perspective might be framed through the researcher's perspective. In this research the relation between the researcher and the respondents permeate every aspect of the research process and determines the quality and quantity of the collected information (Cole, 1991). As such, an important condition for the research is the feeling of trust for the researcher. Only a respondent who feels safe in relation to the researcher will be prepared to share his or her experiences. The relation of trust should allow the respondent to "feel sufficiently free and relaxed to be themselves" (Woods, 1985, p. 14).

To achieve this feeling, in all four studies, I explained to the respondents how the research process would be carried out and that my intention as a researcher was not to examine or to assess them but to listen to their stories and try to interpret their experiences. Further to this they were told why and how they were selected for the study and that they were not required to participate if they felt discomfort. They were also assured confidential treatment of the data.

For me as a researcher the reciprocal relation was important for the trustfulness and *reflexivity*. Therefore, as a researcher I tried to be an active, interested and non-evaluative listener with an open and loyal attitude towards the respondents (Woods, 1985). In much qualitative research the researcher as a person, with his/her interpretative competencies to explore and understand the experiences of the respondents, is an important research instrument. In all four papers the data analysis followed a bottom-up procedure rather than categorizing statements in a pre-determined scheme. As such the research became an inductive process where the empirical data "talked" its own language. My background as a teacher and a teacher educator helped me to recognize different aspects as essential in the collection and interpretation of the data. As Cochran-Smith and Lytle (1990) advocated, teachers' participation in research is needed to increase professionalism and raise the level of teaching.

4.3. Ethical considerations

All participants (teachers, student teachers and pupils) received information about the project concerning their involvement, research aims, methodologies and the use of data. In three of the four studies (paper 1, 3 & 4) video-recording was used as a tool to stimulate participants' reflections. As the research context for study one and three was in a primary school classroom I was very careful to inform the pupils of why I was there and that their participation was voluntary. I also wrote a letter to all pupils' parents to obtain their written permission to be video-record in the classroom. Further to this, I informed the headmasters of the participating schools.

Concerning the student teachers participating in all four studies, they were all informed that participation was voluntary. All participants were carefully informed about the purposes of the studies and asked for permission to quote them in a research context, such as seminars, lectures, conferences and papers, but that they were guaranteed individual confidentiality and anonymity. In all four studies the participants were guaranteed that the video-recordings should be used only for my own research purpose and should not be showed for anyone else. However, it is important to consider the impact that the video-recordings might have had on the participants. In the first study the video-recording lasted a year. One reason for that was to make the student teachers more confident with the idea that they were video-recorded in the classroom. In the third study I installed the video-camera in the classroom to avoid being "in the way" of the participants. In the fourth study the student teachers themselves were responsible for video-recording their work during the experimental workshop. They installed the cameras in one place in the room and did not pay much attention to it during the workshop.

Other ethical considerations worth mentioning are, for example, my efforts to avoid being normative and 'pointing finger' at anyone for not keeping up to their expectations concerning science teaching and learning and expressing 'wrong' views. Instead, I wanted to focus on the participants' stories as the objects of exploration.

5. Results - The four pieces of a puzzle

After almost five years of research on student teachers' learning to teach, it is natural to be critical to the questions of "What are the results?" and "In what way do the results contribute to the research field in science education?" My first approach to this chapter was to make a 'copy-paste' from the abstracts of the four papers and briefly present the results from each paper below. However, considering each paper with its large amount of rich qualitative data, I decided that presenting the results in that way would not do justice to the student teachers' (and mentors') vivid descriptions of their experiences. I realized that these five years of thinking, reading, collecting and analyzing data has resulted in four pieces of a puzzle of a very complex picture of student teachers' learning to teach and teaching to learn. A puzzle where all of the four pieces contribute to the understanding of student teachers' development of a knowledge base needed for teaching during pre-service teacher education. This chapter starts with a presentation of the four pieces (for more reading see appendix 1-4). Then it goes on to, according to the overall research question, present: (1) ways to illustrate and understand student teachers' learning about teaching; and, (2) critical aspects that student teachers experienced within their teaching and learning practices (table 1). As such, the patterns and characteristics of the whole puzzle might tell something about the processes that underpin student teachers' complex journey from learners to teachers.

5.1. Paper 1 - Teaching for understanding - The complex nature of PCK in pre-service teacher education

Paper one initiates a discussion about the knowledge student teachers need to develop in order to be prepared for teaching science in primary schools. As the paper is published in a special issue on pedagogical content knowledge (PCK), and, as it is the first paper in the thesis, it explores the nature of PCK and how it is (or is not) developed during pre-service teacher education. As such, the paper is concerned with science teacher education and examines the difficulties associated with trying to manage learning about teaching as well as the sophisticated development of PCK with pre-service student teachers.

The paper explores how different elements of PCK may be recognized and individually enhanced and highlights the importance of the need for a conceptualization that shifts PCK from an abstract to a concrete construct. The paper further makes clear how the ways in which PCK is understood and conceptualized impacts on how the construct can be interpreted, developed and implemented in science teacher education to create new ways for student teachers to consider the nature of their own professional learning. Further to this, the paper gives an insight into how, through stimulating student teachers' reflections on their own classroom experiences, it might influence their understanding of the complex relationship between their teaching, subject matter content and the context, and how such an understanding might foster possibilities for the development of PCK.

Four student teachers in mathematics and science participated in a project teaching pupils aged 9-11 in physics once a week over a period of two semesters. One third of the lessons were videotaped and the student teachers were later interviewed using the video-tape for stimulated recall. Participants reflected on their classroom practice based on their conceptual understanding of physics, their teaching strategies and their interaction with the pupils in the classroom. The research aimed to consider *what* elements of professional knowledge the student teachers managed to recognize in their practice and how such recognition influenced (or not) the development of PCK.

Through an analysis of the illustrative transcriptions from the four student teachers' reflections in the stimulated recall interviews, the results draw attention to the way each of the elements of pedagogical knowledge, subject matter knowledge and contextual knowledge were (or were not) recognized in their science teaching. In the paper Gess-Newsome´s (1999) two extreme models of teacher knowledge, the Integrative and the Transformative model are discussed in relation to the empirical data. However, the results in the paper support a view of PCK development as a process of transformation of pedagogical knowledge (PK), subject matter knowledge (SMK) and finally contextual knowledge (CK). In some situations the student teachers brought up the different knowledge bases as separate units and in some examples they were recognized by the student teachers in a transformed way. The results illustrate how specific examples of the knowledge bases were recognized and sometimes transformed into PCK. Those specific needs emphasized by the student teachers themselves give an insight into student teachers' struggles and experiences.

Concerning pedagogical knowledge (PK) the student teachers emphasized their need for knowing how to handle their teaching in the classroom such as planning, preparing and deciding on the teaching methods, and how to interact and communicate with the pupils in the teaching situation. They emphasized the use of different teaching methods and ways of explaining phenomena to guide the pupils towards a better understanding; something which also required an act of transformation of PK into PCK.

Concerning their need for subject matter knowledge (SMK) the student teachers emphasized the importance of having strong subject matter knowledge to manage and to feel confident in their teaching. They argued that during their university courses they had learnt different scientific concepts, laws and formulas but this did not necessarily mean that they had understood the content. The relationship between student teachers' subject matter knowledge and their teaching ability, self-confidence and attitudes towards science was clearly evident.

Finally the need for contextual knowledge (CK) concerned knowledge of pupils' abilities and learning strategies, pupils' attitudes about school science topics, the social and cultural environment of the school and pupils' prior knowledge of the concepts to be taught. The need to be familiar with tasks and unwritten rules of the school that influenced their teaching was important, for example, in relation to classroom management. Further to this the pupils' relationships with each other, relations between boys and girls and the group dynamics in the classroom were also stressed.

The student teachers recognized well the role that classroom context played in influencing their teaching. They could see the importance of group dynamics and the need to know their pupils, their ideas, abilities and interests and they emphasized the importance of being aware of the different factors that influenced the classroom climate, particularly in relation to pupils' special problems and needs.

As the data illustrated, it may appear as though the processes of collaboration, teaching and reflection as implemented in the research outlined in this paper enhanced the transformation of student teachers' knowledge to develop their PCK. In their reflections the student teachers gave examples of how the three different knowledge bases in different ways were recognized as important in shaping their teaching. Further to this, the paper concludes that different "knowledges" needed to be transformed, but to encourage this transformation through student teachers' practice; they needed to be confronted by real classroom situations to reflect on. It appears as though the way their knowledge interacted in practice was evolutionary and dynamic and as separate compartments of knowledge SMK, PK and CK were, of themselves, insufficient to manage practice alone; hence the importance of transformation.

5.2. Paper 2 - From lesson plan to new comprehension: Exploring student teachers' pedagogical reasoning in learning about teaching

The results of this paper give an insight into the ways in which student teachers learn about the issues and concerns that shape their learning to teach. During the process of planning, conducting and evaluating a science lesson in a science learning centre at the university, primary science student teacher participants (n = 22) were stimulated to reflect upon critical incidents in order to facilitate identifying their teaching concerns. The process of pedagogical reasoning and action (Shulman, 1987) was used to systematically elucidate different critical incidents that student teachers experienced in order to develop deeper understandings of the complex task of learning to teach primary science.

The results illustrate examples of: (1) critical incidents and (2) their related concerns for learning to teach and (3) teaching needs that the student teachers emphasized (critical incidents → concerns for learning to teach → teaching needs). Concerns in this context were defined as issues that worried the student teachers and/or that they felt anxious about. Needs were defined as things to be done or formulated actions that might resolve a situation. The student teachers' reflections on their experiences during the process, from planning through to conducting the lesson, were grouped into two overarching themes of critical incidents; critical incidents connected to classroom management and critical incidents connected to pupils' attitudes and learning.

The first category of *critical incidents* was connected to classroom management and mostly concerned limitations and frustrations in the teaching situation such as methods and materials, but also their own [lack of] sufficient preparations or subject matter knowledge. These incidents most notably emerged when an experiment failed or when they were asked questions by their pupils, or their accompanying teachers, that they were not able to answer.

The pupils' questions sometimes led to feelings of frustration and discomfort when the student teachers could not answer them. The student teachers also emphasized incidents that emanated from their difficulties in transforming their subject matter knowledge to a primary school practice. The second category of critical incidents was connected to pupils' attitudes and learning. All student teachers highlighted that evaluating the pupils' experiences of the lesson also made them identify important aspects from their own teaching.

The *teaching concerns* that the student teachers felt anxious about were grouped into three overarching questions: How do we adjust instruction to meet the pupils' learning needs and prior conceptions?; How do we stimulate the pupils' interest, "train them in formulating hypotheses", explain phenomena and help them concretise their thoughts?; and, How do we develop our learning about teaching primary science?

As for the first concern, several student teachers emphasized the knowledge of how to be well prepared for the pupils' questions but also for being able to explain phenomena. Deep subject understanding, practical experiments and knowledge of metaphors and analogies appropriate to particular concepts were perceived as important in transforming student teachers' content knowledge in ways that might be meaningful for their pupils. Many of the student teachers came to recognize that knowledge of common misconceptions in science and knowledge of the appropriate level of subject matter were important in shaping a pedagogical situation.

In their pedagogical reasoning all student teachers emphasized their concerns for learning about how to teach primary science and the factors that influenced that learning. The student teachers stressed the importance of self-reflection and the need – as teachers – to review, reconstruct and critically analyze their own and the class's performance. Knowing how to reflect was also emphasized as an important issue for their professional development. They considered it to be important that as teachers, they needed to develop a positive attitude toward gathering and understanding pupils' thoughts and ideas. It was also assumed that if a teacher had a positive attitude towards science teaching then they were also more competent in stimulating pupils' creativity. They also came to see the importance of transforming the theoretical knowledge (of pedagogy and subject matter) into practice as well as displaying sincerity, enthusiasm and joy.

The pedagogical reasoning used in the study also helped the student teachers to recognize their *teaching needs*. These teaching needs were of a different nature. Some aimed at improving the technical effectiveness of the specific teaching experiences and others aimed at addressing more general objective issues applying to many different situations. The five overarching teaching needs are presented and discussed below.

Within their pedagogical reasoning, all student teachers stressed the need for good content knowledge in order to feel more confident in a teaching situation and to know how to explain phenomena to their pupils. One example was the need to put scientific concepts into an everyday situation for their pupils so that they might better understand different phenomena. As they began to recognize the problematic nature of teaching they stressed the need to have a large repertoire of experiments and activities to visualize the different phenomena. Better knowledge of pupils' common [mis]conceptions was also emphasized as an important need. Almost all student teachers emphasized the need for knowing how to reflect and the need – as teachers – to review, reconstruct and critically analyze their own and the class's performance.

5.3. Paper 3 - Primary science student teachers' and their mentors' joint learning through reflection on their science teaching

This study examined what two mentoring primary teachers and two primary science student teachers learned from their common experiences while planning, carrying out, and reflecting on different science teaching activities during a four-week school practicum. The student teachers had had training in scientific knowledge, but only brief experience of teaching. The mentors were well experienced in the pedagogy of teaching and mentoring, but did not feel confident about their science content knowledge and the teaching of science. During the four weeks, two lessons of each of the student teachers and mentors were video recorded. The student teachers and the mentors, working in pairs, reflected on each video-recorded lesson in a stimulated recall session. During their reflections, the student teachers and the mentors expressed an increased understanding of both teaching and learning science, an improvement of their own practice, and a joint learning experience throughout the process of working, observing, and reflecting together.

Shulman's concept of PCK was used to structure the teaching knowledge and several *knowledge elements* were used as codes to analyze the data. Some of these elements were *elements of PCK* according to the model of Magnusson et al. (1999), in particular if participants discussed the use of instructional strategies to teach science (i.e., instructional knowledge), or if they referred to pupils' learning of science content (i.e., knowledge of pupils). Since the participants also discussed issues related to their subject matter knowledge and general pedagogical knowledge, those two were also used as codes.

The results highlight several aspects concerning what the student teachers learned from their mentors. For example, concerning the instructional knowledge the student teachers came to see the importance of making the teaching concrete (e.g., including practical experiments) and linking the content to pressing issues, such as climate change and water recycling, in order to make it meaningful to the pupils. Both student teachers stated that they developed instructional knowledge while observing their teaching and discussing with the mentor how they asked and responded to questions, and dealt with unforeseen incidents during their teaching. Concerning the knowledge of pupils the student teachers described how the mentors taught them to recognize and interpret pupils’ behaviour, for example, silence and body language, which was very useful in the teaching situation. Concerning the pedagogical knowledge both student teachers emphasized how their mentors helped them to learn how to handle the pupils, to interpret classroom events, and to manage teaching in a more general way.

The results also illustrate what the mentors learned from the student teachers. Particularly, both mentors stated that they had learned scientific methods and instructional strategies for science from the student teachers such as hypothesizing and working in a problem-based manner. In their reflections, they described their learning from observing and discussing each other’s handling of unforeseen questions and incidents connected with their own [lack of] subject matter knowledge. The results highlight several situations that made the mentors realize that they needed more scientific knowledge to better grasp the moments and to stimulate the pupils´ interest in learning science.

Finally, the results demonstrated what knowledge the student teachers and mentors developed from the pupils. As the student teachers and mentors learned how the pupils perceived and understood scientific ideas and methods (knowledge of pupils), they were also forced to consider their teaching and how to find new ways to make the content understandable for the children. Further to this, as they identified how the pupils' language, explanations, and questions uncovered their thoughts and preconceptions, they learned how the pupils perceived and understood scientific ideas and methods which were important for their teaching. The mentors and the student teachers stated that they learned a lot from the pupils' explanations, and that they used the pupils' explanations of scientific phenomena as a way of exploring their own ideas of specific concepts.

Overall, both pairs stated that they learned methods of promoting pupils' understanding (e.g., how to make science concrete and link it with everyday life, how to do exciting experiments, how to stimulate pupils' discussions and questioning). The student teachers had better subject matter knowledge than their mentors, but they had no previous experience of classroom management. Nevertheless, the subject matter understanding of the student teachers was not adequate to answer all the pupils' questions and to handle unforeseen incidents. The mentors had a lot of teaching experience, but did not always feel confident in their teaching of science. The results indicate that the learning environment implemented (incorporating opportunities for jointly planning, teaching, observing, and reflecting) was effective in promoting student teachers' and their mentors' learning processes (i.e., the construction and extension of their professional knowledge). The data also clearly indicate that the pupils played an important part in this process.

5.4. Paper 4 - How will we understand what we teach? – Primary student teachers´ perceptions of how to develop subject matter knowledge and a positive attitude towards physics

As all three papers above have highlighted the importance of subject matter knowledge and self-confidence in teaching science, this fourth paper then goes on to investigate *how* different factors, such as practical experiments and subsequent group discussions, contributed to primary student teachers' development of subject matter knowledge in combination with a more positive attitude towards physics.

During an eight-week course, 40 primary science student teachers worked in groups of 13-14 on practical experiments and problem-solving skills in physics. The student teachers were video recorded in order to follow their activities and discussions during the experiments. In connection with every workshop (see 3.1.), the student teachers participated in a seminar; they watched the video recording in order to reflect on how they communicated their conceptions in their group. After the eight weeks of coursework a questionnaire including a storyline was used to elicit the student teachers´ perceptions of their development of subject matter knowledge from the beginning to the end of the course. Finally, five participants were interviewed after the course.

An overview of the 40 storylines indicated that most student teachers perceived that they developed subject matter knowledge in physics during the course (60 % of the storylines were labelled *progressive constant*, 37.5 % were *progressive with ups and downs*, 2.5 % were *stable,* and none were *regressive*). During the analysis of the data (questionnaires and interviews), four categories connected to student teachers' development of subject matter knowledge emerged: (1) Discussing subject matter with a person with more knowledge, or explaining it to others; (2) connecting the theoretical subject matter knowledge gained at the course with a practice of primary teaching through experiments, everyday phenomena, and problem solving; (3) being self-confident; and, (4) seeing the subject matter knowledge as meaningful. They also stressed that the group seminars after the workshops gave them a better picture of how concepts were linked. Further to this they emphasized that their understanding was helped when the physics teacher in the course explained concepts and phenomena with the use of metaphors.

They claimed that the "open design" of the workshops was good as this forced them to look deeper into the subject matter and to discuss it with their peers, to reflect on what they did during the experiments, and to compare each other's results. They also mentioned that it was good to explain concepts and phenomena to each other as it helped them to gain an insight into their own difficulties and how they could be dealt with. When they had to explain phenomena to their peers they were forced to put their own knowledge into words. However, all emphasized the importance of having someone more knowledgeable in the discussions to explain difficult concepts.

In the questionnaires as well as in the five interviews the student teachers emphasized the importance of succeeding with the different practical experiments as a way to connect theory with practice. They mentioned that it was important not to be “given” the knowledge, but instead to work actively to construct their own knowledge. Hence, prior subject matter knowledge to build on was also mentioned by the student teachers as improving their development of subject matter knowledge. In the interviews, all five student teachers highlighted self-confidence as an important aspect both for developing subject matter knowledge, but also for their ability to teach physics. They also emphasized that the group discussion in which they were supported by their peers was important for their self-confidence, and further for their development of subject matter knowledge. Almost all of the student teachers said that they were more motivated to learn physics when they felt that the knowledge was meaningful to them and could be used in their future teaching, something which also influenced their own development of subject matter knowledge.

As for their attitudes, all 40 student teachers mentioned in their written questionnaire that their attitudes towards physics had changed during the course. Most referred to their secondary school physics as the cause of a negative attitude towards physics when they started the program, but they said they felt more positive about it at the end. Everyone said that their attitudes towards physics had improved, and that they were now more curious about things that they did not know about before. Almost all student teachers highlighted the connection between the feeling of success (e.g., to manage an experiments) and a positive attitude. Several student teachers emphasized the connection between the sense of uncertainness and their attitudes towards the subject. However, all of them stressed that working in groups with everyday experiments (with no given answers) challenged them which also made them develop a more positive attitude towards learning and teaching the subject.

5.5. The puzzle as a whole - Learning to teach and teaching to learn

So, in what way do the results outlined in the four papers contribute to the knowledge of student teachers' learning to teach? The overall question that this research has aimed to answer has a pragmatic character important not only for the field of science teacher education but also for its implications. The practices and processes highlighted in this thesis have aimed to answer the question: "In which ways can student teachers' learning about teaching be illustrated and understood in terms of the critical aspects that are experienced within their teaching and learning practices?" This section will present the critical aspects (table 1, p. 82) that student teachers experienced within their teaching and learning practices, and the ways in which student teachers' learning about teaching can be illustrated and understood. Finally I will summarize those aspects through two claims concerning student teachers´ learning to teach primary science.

As a case study reports on the complex dynamic and unfolding interactions of humans and factors in real contexts that are inevitably unique, the student teachers' rich stories make an important contribution to the puzzle as a whole. Hence, my contribution to the research field of science [teacher] education is to, through empirical studies of different interactions in different contexts, try to highlight the nature of the gap between theory and practice and, in so doing, try to connect the "what is taught in teacher education" with "what is experienced and recognized by the student teachers themselves". However, the research that the four papers build does not intend to *measure* student teachers' learning, but instead to give an insight into the processes that underpin that learning. The results present "critical aspects" important to the student teachers in shaping their understanding of their own practice. Thus, the four papers indicate that in order to discuss student teachers' learning to teach through teaching, student teachers' own personal stories must be carefully investigated and analyzed.

The first way in which student teachers' learning about teaching can be illustrated and understood concerns the *research design*. The research outlined in all four papers investigates different contexts for teaching and learning science through a systematic exploration of the nature and substance of the student teachers' interactions with different individuals. Within the four studies they interact with the young pupils in school and in the science learning centre, with their mentors and with the teacher educators and physics teachers during a university course. Also, within all four studies, the student teachers' interaction with each other (in pairs or in groups) gives an important insight into the complexity of their learning to teach science. Another way to illustrate and understand student teachers' learning about teaching concerns the *methodology* (e.g., methods to collect data) with which this research was conducted. As the results in paper one, three and four indicate, the stimulated recall methodology helped the participants to recognize and in fact emphasize aspects within their teaching and learning of science. Further to this, the story-line method used in paper four helped student teachers to not only indicate important aspects for their development of subject matter knowledge in physics, but also to explore *why* those aspects were critical.

A third important aspect in order to illustrate and understand student teachers' learning about teaching concerns the way student teachers (and mentors) managed to *recognize* both their needs for different knowledge bases and the way these impacted the possible foundations of PCK. The way each of the knowledge bases (in paper 1), concerns (in paper 2), knowledge elements (in paper 3) and subject matter knowledge and attitudes (in paper 4) were recognized and explained by the participants as well as the interplay between them suggested that, through reflection with mentors and peers, transformation into PCK for primary science teaching might well be occurring.

Concerning critical aspects that were experienced within the student teachers' teaching and learning practices a common pattern in the four studies was how the student teachers came to recognize that a lack of subject matter knowledge (SMK) made it difficult for them to relate phenomena to everyday situations, but that subject matter alone was not sufficient. Different knowledge needed to be transformed, but to encourage this transformation through student teachers' practice, they needed to be confronted with real classroom situations to reflect on, and learn from these concrete examples. As such, the student teachers often stated that they needed more work with representations and experiments and activities that could be used in the primary science classrooms to handle pupils' difficulties in understanding certain topics.

Another critical aspect which was evident in all four papers was the importance of subject matter knowledge to handle the situations in the classroom. Finding out about the need for subject matter knowledge might be considered as an obvious result, but the fact that student teachers, through reflecting on their teaching experiences, *themselves* identified their needs is of great importance. Concerning their need for subject matter knowledge, the interface between SMK and PCK proved to be critical in the process of how to transform the science content which further indicated the complex relationship between subject matter understanding and the subsequent PCK development. In paper one, two and three a critical aspect that was highlighted was that each of the student teachers experienced a gap between the subject matter knowledge they had gained at the university and the physics they taught in school. This gap emanated partly from their difficulties in transforming their subject matter knowledge and in relating theory to practice, largely derived from a lack in their own subject matter knowledge. The results from paper one, two and three support the ideas of Gess-Newsome (1999) and Hashweh (1987) who emphasized that the development of teachers' SMK and PCK are related in complex ways, and that both are crucial to good science teaching. The importance of subject matter knowledge to be meaningful for primary teaching and to be connected to everyday situations was further highlighted as a critical aspect in paper four. However, all results support student teachers´ need to experience how the classroom context influence their ability to teach and learn science. The teaching together with a peer or a mentor in paper one, two and three and the group discussions in paper four were also important critical aspects of the studies and offered access to the reasoning underpinning student teachers' ideas and actions. Another critical aspect was the importance of "grasping the moment" (i.e., take the chance when it comes) to initiate discussion with pupils and examine pupils´

ideas and concepts in ways that could not be totally planned in advance. For example, in the interaction with the pupils they saw into the problematic nature of teaching and how through a failed experiment discussion about the nature of science and scientific experiments could be examined. Another critical aspect was how the student teachers realised that not every pupil enjoyed experimenting which made them question their initial aims. The student teachers also had a preconceived notion that pupils were curious by nature and always asked questions about "how and why". During their demonstration they found out that this was not always the case. Further to this the student teachers in general emphasized the importance of giving the pupils good motives for learning science. Concerning pedagogical knowledge, a critical aspect that the participating student teachers experienced within their teaching and learning experiences, which was also a common pattern in paper one, two and three, concerned the student teachers´ difficulties to see the pupils' needs and interpret their feelings. Further to this the student teachers experienced difficulties to manage different situations during teaching such as dealing with conflicts, encouraging all pupils to participate in activities, and *seeing* and *hearing* all pupils. However, an important issue was then to learn to see and interpret pupils' engagement and activities in the classroom. As the student teachers [and mentors] reflected together in the stimulated recall sessions and in the group seminars they stressed that they helped each other to see, recognize, and interpret critical incidents and situations in their teaching activities. Those activities, the student teachers claimed, helped them to find a different (deeper) dimension in their own teaching.

Within all four studies the student teachers gave several examples of critical aspects of their *learning experiences*. One example was how they learned from pupils´ (paper 1-3) or from their peers' (paper 4) explanations and questions, which led them to an understanding of what might be difficult and too abstract for the pupils in a teaching situation, and also to an awareness of their own subject matter knowledge. As one of the mentors in paper three explained; those experiences had taught her to take a step back and take a broad perspective while observing and reflecting on how she and her student teacher asked and responded to questions and unforeseen incidents. Another example was how they learned a lot through exchanging feedback and critique with their peers and their mentors (paper 3) and also through criticizing themselves. They stressed that they learned how to use specific teaching methods to represent subject content, to enhance pupils´ understanding, and to develop their attitudes and motivation. Another aspect within their teaching and learning experiences which they highlighted was that they learned from the pupils as they practiced strategies that were fruitful in challenging and “reorganizing” the pupils´ understanding. Trying to analyze others’ thoughts and what things they considered difficult helped them to shift from understanding something yourself, to explaining it to others. Another critical aspect within the student teachers’ teaching and learning experiences and hence, a way to portray and understand student teachers’ learning to teach was that all four papers provide insight into how aspects such as self-confidence, a positive attitude towards science, the usefulness and the meaningfulness of scientific knowledge became important aspects in primary science student teachers´ teaching and learning science. Concerning their development of SMK in physics practical experiments and everyday knowledge (e.g., the experiment in the elevator in paper 4) was particularly good as it could be used in a primary school setting and was easy to connect with everyday situations. The student teachers in all four studies also mentioned that they had realized the importance of starting with science in primary school. In table 1 the critical aspects are clustered into the three different knowledges; subject matter knowledge (SMK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK). The first knowledge (SMK) lists conditions concerning student teachers´ subject matter knowledge to be useful to primary science teaching and teacher education. The second knowledge (PK) lists aspects of things that student teachers should know or be able to do concerning general elements regarding teaching, classroom organization and management, instructional strategies and classroom communication. The last knowledge (PCK) mostly refers to aspects that are crucial to the development of PCK.

Critical aspects related to subject matter knowledge (SMK)	• SMK is important to handle the situations in the classroom but SMK *only* is not enough to transform the science content into teaching • SMK at university courses should build on practical experiments and everyday knowledge in order to become meaningful and relevant for primary school teaching
Critical aspects related to pedagogical knowledge (PK)	• Important to be flexible and to take the opportunity to discuss and examine pupils´ ideas and concepts • Important to see the pupils' needs, interpret their feelings, manage dealing with conflicts and encourage all pupils´ participation • Important to practise strategies that are fruitful in challenging and "reorganizing" pupils´ understanding • Important to give pupils good motives for learning science
Critical aspects related to pedagogical content knowledge (PCK)	• Teaching experience, self-reflection and exchanging feedback and critique with peers and mentors are important • Self-confidence and a positive attitude towards science are important • The relation between SMK and PCK is critical in the process of how to transform the science content to promote pupils´ understandings • Ability to *recognize* and explain the need for different knowledge bases, the interplay between them and the way these impact on teaching primary science are important

Table 1. Critical aspects that student teachers experienced within their science teaching and learning practices

In summary, the results of the four papers highlight student teachers´ difficulties in learning and understanding the science content for themselves, as well as transforming their knowledge into appropriate pedagogical practices in primary school. The critical aspects listed above, as well as student teachers´ detailed perceptions of their teaching and learning experiences, indicate some of the complexity inherent in teaching and learning about science teaching.

First, as the relation between SMK and PCK proved to be critical in the process of how to transform science content, student teachers needed to understand the science content for themselves. Secondly, student teachers needed to know how to teach the content in a way that might promote pupils´ understanding (i.e., they needed to possess and develop PCK). Hence, considering the range of critical aspects experienced by these student teachers, it is reasonable to suggest that pedagogical content knowledge needs to be understood as dynamic knowledge generated in practice mediated by the capability to combine or blend individual knowledge bases together so that they are transformed in practice. In order to summarize the results from the four papers in this thesis, I suggest two claims which will be further discussed in the following sections:

1. Student teachers experience a problem concerning the relation between what they learn both in science content courses and courses of pedagogy, and that knowledge that is actually needed in their teaching in a primary school context.

2. There is a consistent lack of attention to, or demonstration of, pedagogical content knowledge in science content courses as well as in courses of pedagogy which results in difficulties for student teachers in transforming their subject matter knowledge through pedagogical practice into a form that is meaningful for their pupils’ learning of science.

The critical aspects outlined above demonstrate that teaching science is not so much about making the content simple, it is about teaching the content in ways that make it understandable to pupils by stimulating their interest and learning. However, there is not one correct way of developing pedagogical content knowledge and not one correct way of teaching student teachers how to develop it. Student teachers learn in different ways as do the pupils they teach – each have different abilities, interests and learning needs. Therefore, as highlighted by Bishop and Denley (2007), learning to teach (as illustrated through the development of PCK) could be viewed as a sophisticated process of combining different knowledge bases together in particular contexts; all of course influenced by individual pupils, classes, colleagues, topics, etc. Further to this, if it was actually possible to define the knowledge needed for teaching, it might assist new teachers to know better for themselves, how to work to learn to acquire it.

6. Discussion – Primary science student teachers´ complex journey from learners to teachers

For teachers the construct of pedagogical content knowledge (PCK) has largely been used to define teaching as a professional practice. Shulman (1986, 1987) conceptualized PCK as "the category [of teacher knowledge] most likely to distinguish the understanding of the content specialist from that of the pedagogue" (1987, p. 8). Shulman further claimed that teachers need strong PCK to be the best possible teachers. Thus, considering the second claim suggested above, it might well be argued that also teacher educators' PCK (in science as well as in pedagogy courses) should include knowledge about how to promote a student teacher's journey from learner to teacher. Furthermore, with respect to student teachers´ difficulties in understanding science content (suggested in claim one above and which was highlighted in all four papers), teacher educators´ PCK needs to demonstrate how they have developed and come to use different "ways of representing and formulating the subject that makes it comprehensible for others" (Shulman, 1986, p. 9). Shulman (1986) noted that teacher education programs in general seem to be based on the view that student teachers will teach effectively once they have acquired subject matter knowledge, strategies of innovative curriculum and have practiced using them. However, as many beginning teachers feel so insufficient prepared for their teaching that the term "reality shock"

(Veenman, 1984) has come to be frequently used, this approach to teacher education might seem to have failed. This touches at the very heart of the question about what it really means to acquire the knowledge base needed for teaching and how it might be supported during teacher education. Korthagen et al. (2006) stressed that the learning of student teachers is only meaningful and powerful when it is embedded in the experience of learning to teach.

The papers in this thesis support the idea that for student teachers' learning to teach, a crucial issue has proved to be the interaction between pupils as well as mentors and peers in the teaching situation. Therefore, teacher educators need to create situations where these interactions become natural parts of teacher preparation. In such a way, one precondition for student teachers' learning to teach might then be to recognize and to further understand important elements needed for teaching science while actually teaching it.

This thesis illustrate the idea that the sharing of reflective experiences, the reconsideration of what it means to understand the particular concepts as a learner and a teacher and the learning about the "how", are all embedded in the practice of teaching. However, as the components in teacher knowledge will interact in a highly complex way, it is important for student teachers to understand not only the particular components, but also to understand the contexts in which they develop, how they interact and how their interaction influences the thinking about, as well as the act of, teaching. Therefore, the subtitle "Primary science student teachers' complex journey from learners to teachers" highlights three issues that I want to explore and connect to the theoretical background as well as the empirical data. First the *journey,* then the *complexity* and finally *from learners to teachers.*

6.1. The journey

Let us begin to illustrate teacher education in the way it is researched in this thesis, with a journey where every stop represents an activity or an interaction with different people and places through which the student teachers experience different critical aspects (table 1).

First, it is reasonable to suggest that all student teachers travel on different personal learning journeys, interpret and learn from the interactions in different ways. The journeys might take many different turns and contain several interesting meetings in different contexts. However, it might well be argued that at the centre should be the student teachers´ experiences and their reflections and analysis of these specific experiences. The student teachers' learning journeys presented in this thesis include three "stops" where every stop represents an interaction between student teachers and places (such as teacher education or primary school) as well as other actors (mentors, pupils or teacher educators). As university coursework and school based practice are integrated all through the 3,5 - 4,5 years of teacher education program, the three stops presented below are not related in time.

6.1.1. Interaction with teachers in science courses as well as in courses of general pedagogy at the university

One "stop" of the student teachers' complex journey from learners to teachers is the interaction with university teachers and activities in science courses as well as in courses of general pedagogy at the university. Student teachers enter their programs not only with a concern to learn about teaching [science], but also with at least 12 years experience of school teaching - but from the other side of the teachers' desk. They are familiar with classrooms and the school context and in most cases they have their own perceptions and beliefs about what it is to teach science and how they might learn to teach. For teacher educators then to give student teachers opportunities to confront and redefine those existing beliefs might be considered as a challenge.

There has been an ongoing discussion about the relevance of university based courses in teacher education. Pinnegar (1995) stated that teachers often criticize the teacher education coursework that was offered them as too theoretical and "not merely unhelpful but unrelated to issues in classrooms" (p. 56). This view is supported in paper one, two and three in this thesis as the student teachers during their journey often experienced difficulties to connect theoretical pedagogical knowledge and subject matter knowledge gained in their university courses to a primary school context. Further to this, student teachers often ask for practical work such as "tips and tricks" or "activities that works" (Appleton, 2003) which are easy to connect to their future teaching. Similarly, as confirmed in the papers in this thesis, student teachers often argue that their university courses contain too much theory and that the real learning takes place in school during practicum experiences. Thus, student teachers seem to be more interested in courses that focus on what a teacher needs *to do* as opposed to what a teacher needs *to know*. Hence, as highlighted by Russell (1997) and Korthagen (2001), for many student teachers, coming to understand teaching as being problematic and therefore moving beyond expectations of learning to teach as being "told how to do teaching", is a constant challenge.

All through the four papers it has been highlighted that the student teachers had difficulties connecting the theoretical pedagogical and subject matter knowledge gained at the university to relevant primary science teaching practice. However, it might be reasonable to suggest that student teachers also need to be able to theorize practice in order to know and be able to articulate the *what*, *how* and *why* of teaching. In her self-study, Pinnegar (1995) returned back to school after 20 years of work as a teacher educator in order to explore the dilemmas of practice that she experienced during her first year of teaching. She wanted to see if she now, after 20 years of academic coursework, could teach school students in the ways she was teaching her future teachers to do. When reflecting on her teaching she was able to identify the ways in which theory guided, framed and emerged in her thinking about practice. Bearing in mind the theory-practice gap mentioned above, she concluded her paper arguing that teacher educators:

"…should get beyond the questions whether theories, ideas, and research taught in teacher education programs are evident in the practice of teachers, to focus instead on *how such learning is evident.* Perhaps some of the problems of practice might be more clearly explained by examining how theories emerge rather than discussing whether they do or do not." (Pinnegar, 1995, p. 67)

Therefore, it might be argued that in teacher education courses it is not enough to simply present student teachers with suggestions for teaching practice (i.e., how to connect theory to the teaching practice). Student teachers also need to be engaged in theorizing about *how* to learn to teach as well as theorizing about those suggestions for practice.

Just as people visit different places on a journey and experience the places in different ways depending on their interests and previous knowledge, student teachers enter their primary science teacher education programs with different pre-knowledge and also with different attitudes towards science and science teaching. In paper one and four, there were examples of student teachers who stressed that they experienced physics as a difficult and sometimes boring subject and that some even tended to avoid physics in their future teaching. Others maintained that they had always liked the subject and saw science teaching as a way of stimulating students' problem solving skills. However, even though the student teachers entered the primary science teacher programs with different views on teaching science, it might well be argued that they all shared an interest in interacting with primary students and the exciting experiences that these interactions might offer. A journey might offer a range of activities, meetings and interactions with people as well as places that challenge people's conceptualizations and interpretations. In the same way, teacher education courses offer a range of experiences for student teachers to challenge and conceptualize their view of science and science teaching.

As mentioned above, the student teachers in this thesis often stressed that they had difficulties connecting the theoretical knowledge gained at the university to a primary school context. There have been several attempts to understand approaches of teacher education that might assist in shaping alternative conceptualizations of the theory-practice gap highlighted in this thesis. Kessels and Korthagen (2001) and Korthagen et al. (2001) used the constructs of *episteme* (the theoretically derived knowledge) and *phronesis* (the practical knowledge arising out of specific experiences) as a way of responding to the difficulties associated with connecting theory to practice. Episteme consists of assertions of a general nature that applies to many different situations and problems and is often described in abstract terms. On the other hand, phronesis is a form of practical knowledge that is derived through understanding of specific situations and cases (Korthagen et al., 2001).

When student teachers, like in paper one, two and three in this thesis, are encouraged to incorporate *theory* into their practice, they often have difficulties in bridging the gap and close the "zipper" (Kelchtermans & Hamilton, 2004) between the two. There is also a common view of student teachers that in teacher education programs the "real" teaching is not informed by the university's theoretical coursework but in the classrooms. Therefore teacher educators need to get beyond questions of whether theories, ideas and research taught in teacher education programs are evident in the practice of teachers, to focus on how such learning is evident (Loughran, 2006). One way of so doing within the university coursework was elaborated in paper two. The research project in the science learning centre was based on the assumption that if a student teacher is encouraged first to identify and further to reflect on critical incidents (Tripp, 1993) in their own practice, that they might then conceptualize aspects of their practice that they need to address in order to meet their explicated pedagogical concerns.

As indicated in paper four, the level of student teachers' development of, for example, subject matter knowledge in a university physics course was highly dependant on the usefulness and meaningfulness of that knowledge in relation to their teaching of the subject. Hence, modelling Shulman's (1986, 1987) notion of PCK (as an amalgam of content and pedagogy) in teacher education might be helpful to understand not only *what* knowledge (content) might be useful for student teachers, but also *how* (pedagogy) it might be used and further developed in a teaching practice.

Finally it might be assumed that one reason that student teachers confront difficulties in attempting to connect their subject matter knowledge of science to their teaching practice is linked to the different characteristics of both science and pedagogy. In the context of science teacher education as it is researched in this thesis, the subject matter knowledge comes from science disciplinary fields, while the understanding of teaching comes from the field of pedagogy or education. Hence, it is reasonable to suggest that this separation reinforces a model of science that is different from models of teaching and learning science. In the science discipline scientists construct their theories carefully and systematically and test hypotheses empirically so that explanations have a firm basis in facts. Further to this, according to Cohen et al. (2007) scientists tend to be concerned with relationships amongst phenomena that are systematic and controlled. On the other hand, the immense complexity of human nature and the elusive quality of social phenomena contrast strikingly with the order and regularity of the natural world (Cohen et al., 2007). In humanistic and social science (e.g., pedagogy) individuals´ behaviour is perhaps best understood by researchers by sharing their frames of reference. Therefore social sciences might be seen as a subjective rather than an objective undertaking as a means of dealing with the direct experience of people in specific contexts where the social scientist understands and explains social reality through the lens of the participants (Cohen et al., 2007).

Myrdal (2007) discussed the differences between the cultures of natural science and human/social science and stressed that natural science and human science must accept each others research methods and have insight into each others theoretical perspectives in order to respond to “big questions” in the life of human. However, it might be well argued that the questions about “teaching and learning” are considered as such big questions. Hence, as *science education* as a research field investigates people’s conceptions, teaching and learning of science and not the nature *per se*, it is reasonable to suggest that the epistemological questions of how such knowledge can be attained are as much related to humanistic and social science as to natural science. This might in turn influence the attention to *what*, *why* and *how* science is taught in science teacher education in order to prepare student teachers for teaching in a primary school context. University science is characterized by its own culture which is different from the culture of primary school science. The student teachers bring with them the language, concepts and methods of university science into primary school which results in conflict. Further highlighted in the research literature (c.f. van Driel et al., 1998) is the situation whereby science teachers approach scientific problems differently than scientists due to their understanding of the pedagogical implications of learning science (hence the distinction some draw between science and science Education). The separation between the science content and pedagogy (i.e., understanding of teaching and learning) might lead student teachers to struggle in adjusting their understanding of science per se to understanding of science education. Hence, in order to "bridge the gap" between university learning of science and primary school teaching, a challenge that science teacher education faces is finding ways of gaining insights into how the different ontological perspectives of science and pedagogy (in the university as well as in the school context) influence student teachers´ teaching and learning about teaching.

6.1.2. Interaction with pupils in the primary school context

Another "stop" in student teachers' journey is the interaction with primary school pupils in the school context. As highlighted by Morine-Dershimer & Kent (1999), student teachers need opportunities to practice instructional processes in the actual lessons that they plan, conduct and evaluate so that they can learn from review and discussion of each other's lesson. Further to this, Loughran et al. (2006) argued that opportunities for student teachers to experience a sense of frustration in teaching matters if they are to move beyond being comfortable with tips and tricks alone (that is to see and feel the problem in order to decide to do something about it).

Lederman and Gess-Newsome (1992) used an analogy between Shulman's (1986, 1987) conception of teachers' knowledge and the ideal gas law. Just as the ideal gas law does not perfectly describe the behaviour of real gases it is difficult to perfectly describe classroom teaching and the conception of teachers' knowledge. In a similar way, if different individuals visit different places on a trip around the world, the student teachers will experience the interaction with primary school pupils in the school context in different ways depending on their previous knowledge and experiences of the school context, their own personalities and the different individuals they meet. Further to this, their experiences will also depend on how well prepared they are for the trip.

Compared to a journey, if people have learned different languages they are better able to communicate with the citizens and to understand their feelings and ideas. In the same way, student teachers who have learnt how to communicate with pupils, who have learnt to interpret their conceptions and ideas and to communicate the science content in order to make it comprehensible for pupils, are also better prepared to manage the complexity of teaching science. In the same way as the student teachers in three of the four papers highlighted the importance of being well prepared for science teaching, it might be assumed that someone who goes on a journey would better benefit from it if they, for example, had carefully studied a traveller's guide.

The student teachers in two of the four studies interacted with pupils in the primary school context. Lave & Wenger's (1991) notion of "learning as participation" and Wenger's (1999) concept of "community of practice" could well be used to explore this destination of student teachers' journey. However, for student teachers to become more central participants in the community of school practice they are required not only to interact with the pupils but also to identify themselves as members in the "teachers' society". Thus, central to the notion of "community of practice" as a means of acquiring knowledge is the *process* by which a student teachers move from peripheral to full participation in the community (i.e., going from learners to teachers). Thus, in order to capture and better understand the community of practice student teachers need opportunities to interact with students as well as teachers. That is why the context in which the interaction takes place, for example the social and cultural environment of the school (Gess-Newsome, 1999), also becomes an important factor as to how student teachers experience the destination of their journey.

Further to this, to foster the development of student teachers' professional knowledge of the amalgam that is PCK, they need tools to help them attend to issues in the interaction with their pupils. Such tools could be exemplified as teaching needs (paper 1 & 2) or PCK elements (paper 3) to be used in *their* classroom practice. Returning to the journey, even though exploring the city on your own may also promote learning experiences, the tools mentioned above could be illustrated through the travellers guide book by promoting several "tips and tricks" of how to enjoy the destination.

6.1.3. Interaction with mentors in the primary school context

The third "stop" in student teachers' complex journey from learner to teacher that was explored in this thesis is the interaction with mentors in the primary school context. Paper three aimed to document and understand two primary science student teachers' and their mentors' joint learning through reflection on their science teaching during a four week practicum. In general, school based teacher education requires mentors to share their expertise with student teachers in a context of cooperative learning. As such, mentoring is a way of helping student teachers to study their practice with others so that alternative perspectives and possibilities might become apparent and could be acted upon. For example, Maynard and Furlong (1993) defined mentoring as a "nurturing process in which a more skilled or more experienced person, serving as a role model, teaches, sponsors, encourages, counsels, and befriends a less skilled or less experienced person for the purpose of promoting the latter's professional and/or personal development" (p. 29). Halai (2006) identified a mentor's roles as those of expert-coach, subject specialist, critical friend, and learner. However, as paper three concerned the *joint* learning between the student teacher and the mentor, the mentor as a learner-perspective stressed by Halai (2006) becomes an important issue.

As highlighted in paper three, the way in which a student teacher experiences the interaction with the mentor in the school based practice (the ‘stop’ in the journey) is based on a range of interrelated tasks. Further to this, the results in paper three indicated that as the student teachers could be seen as a catalyst for mentors in clarifying their thoughts and needs as teachers, the interaction between student teachers and their mentors also promoted advantages for the mentors. The mentor should observe the pupils as well as the student teacher and further discuss and analyse the student teachers’ teaching practice. Further to this, a key feature in mentoring is allowing student teachers access to the ‘craft knowledge’ of mentors where one task of the mentor is to model teaching and general classroom management (Lazarus, 2000). However, as stressed in paper three, to ensure thoughtful interactions, mentors and student teachers need to listen to each other’s ideas and give each other instructive feedback. This will improve mentors’ abilities in dealing with student teachers, as well as improve the student teachers’ educational experiences in the classroom.

The mentors have daily experiences of communicating with pupils in school, teaching students with widely different abilities and motivations etc. Hence, it might be reasonable to suggest that mentors normally know which way is best to organize the class, to give out instructions and to help student teachers to deal with conflicts, encourage all pupils to participate in activities and finally to *see* and *hear* all pupils (critical aspects in table 1). As such, the mentors ‘open up’ their classrooms for student teachers allowing them to observe and discuss their teaching. However, as the mentor possesses both a theoretical and practical perspective, it might be assumed that one goal of the mentoring process should be to bridge the ‘doing’ and the ‘knowing *why* one is doing’. However, Furlong and Maynard (1995) found that mentors were able to talk about the content of their knowledge, but describing how they applied that content in the classroom was much harder.

In order to support student teachers, mentors must be able to articulate beliefs, views, knowledge and know-how, which may be implicit or intuitive, in a way that suits both the mentor and the student teacher (Lazarus, 2000). As such, this stop on a student teacher's complex journey from learner to teacher very much relies on the interaction and relationship between the mentor and the student teacher. The mentors observe student teachers' lessons and provide oral or written feedback which should be based on openness and confidence between the mentor and the student teacher. As the student teachers in paper three also provided oral feedback on their mentors, the importance of on openness and confidence between the two became even more important. Another dimension is that the mentors also played an important role in assessing student teachers against formally prescribed criteria, decided by the teacher education curricula. This shift from critical friend to assessor is not always easy or comfortable. Lazarus (2000) highlighted the importance of a good relationship between the mentor and the student teacher.

"The mentor should be a good listener, a critical observer or a person who encourages and challenges the trainee to reflect on different aspects of teaching and learning. Mentoring relies heavily on the development of professional and personal relationships as most work is carried out on a one-to-one basis" (p. 112).

Book (1996) noted that mentors have begun to realize that their role in supervising student-teachers has enabled them to learn more about teaching. In helping novices to improve, they have to articulate more explicitly what they know and believe about teaching. Having to articulate their actions to another person sharpens up mentors' thinking and makes them re-evaluate much of their unconscious or implicit assumptions (Lazarus, 2000). In paper three the joint learning between the two student teachers and their mentors was carefully investigated and discussed in relation to their development of pedagogical content knowledge. Thus, what this paper brings into light is that this 'stop' on the journey (i.e., the interaction between the student teacher and the mentor in the mentoring process) is not only a part of the learning journey of the student teacher but also of the mentor.

Let us return to the metaphor of the journey. It might well be argued that in order to benefit the most from a guided tour requires the guide to be able to make explicit his/her knowledge about the different places. Hence, one important aspect for the guide must then be to help the visitor to see and recognize aspects within the area that he/she would not have been able to see alone. Thus, the guide could provide the visitor with information about what to see, how to act, communicate and respond to people as well as places with which they interact during the tour. However, the guide must not only be able to know about the area, but also be able to conceptualize this knowledge and tell interesting stories about it. It could well be argued that another important aspect of the guiding metaphor which was highlighted in paper three might then be that when preparing for and then later guiding the visitor, the guide will see and recognize aspects within the area that he/she might not have noticed before. Further to this, the guide has to articulate more explicitly what they know about the places. Hence, similar to the mentors, having to articulate their knowledge about the different tourist attractions to a visitor might "sharpen up" a guide's thinking and make him/her re-evaluate much of his/her unconscious or implicit knowledge.

In the same way, the mentor might act as a guide for student teachers' learning in the classroom. The interaction with the mentor provides opportunities for student teachers to teach and get feedback in order to develop confidence and learn about their teaching as well as their students' learning. Hence, planning, conducting and evaluating teaching together with the mentor become important for the student teacher in terms of developing self-confidence and knowledge not only of what to teach but also of why and how. Similar to a guide who might learn more about the places to which he/she brings the visitor, paper three supports the notion that mentoring serves as a catalyst in the mentors' thinking. This initiates a process of growth or development of the mentors, as they re-examine aspects of their professional lives. To guide student teachers' learning, mentors need to understand how student teachers think and learn about science teaching. They must also have knowledge about specific strategies of science teaching, students' learning, and the subject matter in order to guide their student teachers in learning to teach science. Hence, this "stop" on a student teacher's complex journey from learner to teacher then provides opportunities for both student teachers and their mentors to directly verify and develop their own teaching skills and to step back and to reflect on each other's teaching.

6.2. The complexity

Why is the journey complex? It might be assumed that one answer to the question concerns the characteristics of science teaching. The student teachers' (and mentors') voices in the four papers all hinted at the various ways in which they experienced their primary science teaching and learning. Even though the student teachers had tried the experiments several times, they still failed. Even though they felt that they had prepared for difficult questions from the pupils, they received unexpected questions that they could not answer. Even though they thought they knew about the pupils' pre-conceptions, they were surprised that the pupils often knew more than they had expected. Even if the mentors had more than twenty years of teaching experience, they felt like novices when actually teaching science.

Already in 1986, Clark and Peterson stressed that "classroom teaching is a complex social process that regularly includes interruptions, surprises, and digressions" (p. 268). Teaching science requires a diverse knowledge of resources such as materials, curricula, students, methods and strategies, most of which are acquired over several years. These resources then form the tools that teachers use in order to promote pupils' learning. During their pre-service programs student teachers should have the opportunity to become familiar with those tools. Further to this, the complexity of teaching derives from several other aspects such as the diversity of students in school, the changing world of society as well as of school organisation and changing demands and requirements on teachers.

Another reason for the complexity is the structure of science teacher education. During their years of education, the student teachers in this thesis entered several different arenas for learning. They interacted with courses and university teachers from different cultures (such as science faculty and faculty of pedagogy) with different ontological perspectives, which, as highlighted in the papers, means they do not always experience them as being in agreement in the actual primary school context in which they will teach.

Finally, it might be reasonable to suggest that the complexity in a student teacher's journey from learner to teacher also depends on the nature and quality of reflection, in university courses as well as in school based practice. In this thesis reflection has been a major issue and in all four papers different tools have been used to monitor student teachers' reflections. Normally student teachers are encouraged to reflect on their teaching practices, how they managed to reach their goals and their experiences of teaching. Those reflections are often documented in portfolios and discussed in seminars. However, the question still remains as to *how* do they reflect and what is the quality of their reflections. Björklund (2008) stressed that student teachers (as novices) have a limited ability to see and interpret classroom situations and therefore they are only able to reflect superficially on their teaching. Hence, it is important not only to encourage student teachers to reflect, but also to evaluate the depth and status of that reflection. It might be assumed that student teachers learning to teach also include "learning to reflect", which then might hint at the complexity of a student teacher's journey from learner to teacher. Further to this, for teacher educators to evaluate and reflect on student teachers' teaching and learning science, they must also be able to see and recognize student teachers' difficulties, needs and concerns.

6.3. From Learner to Teacher

Interest in better understanding the knowledge base needed for teaching and how it is developed has been running high for at least the last twenty years. As Berliner (2004) outlined, it takes 5 to 7 years to acquire high levels of teaching skills where the teacher is no longer surprised by what happens to them in their schools and classrooms. Berliner (2004) added that this period might be shortened, or be made richer if some coaching were to take place. Shulman (1987) began his paper with a portrait of teaching expertise asking: "What does Nancy (the person portrayed as an expert) believe, understand, and know how to do that permits her to teach as she does? Can other teachers be prepared to teach with such skill?" (1987, p. 3).

However, the student teachers' vivid "stories" in this thesis support the ideas of Bishop and Denley (2007) that:

"…becoming a science teacher is not only a case of learning a predefined set of procedures and a static body of knowledge, it is about engaging with a dynamic and exciting subject and facing the challenges of presenting to students in an accessible way (p. 2)".

The journey from learner to teacher is a never ending process of investigating, reflecting and analyzing one's own activities in the classroom in order to formulate one's own personal professional theories and to use these theories to guide future actions. Further to this, it seems reasonable to suggest that a strong sense of self-motivation is needed to drive student teachers to continue their learning journeys as life-long learners. Even though student teachers might often be looking for safety in their teaching, it is reasonable to suggest that they also need opportunities to "take risks" in order to learn through experiencing the discomfort of being less certain of what is [or might be] happening. In so doing, they may begin to capture and better understand the complexity of [science] teaching and learning.

Finally then, let us return to the entire subtitle "Student teachers' complex journey from learners to teachers." However, given the nature of teaching, it is reasonable to suggest that there is a number of "unknown domains" of teachers' practices that teachers need to explore in search of answers that will guide their future actions. As such, teacher education is a beginning place for teachers' professional learning journeys, not an end. Therefore teacher education needs to foster and inspire student teachers for their ongoing professional learning journey. Further more, teacher educators (and student teachers themselves) need to research student teachers' experiences and concerns in order to learn to teach about teaching more effectively.
Munby and Russell (1994) suggested the authority of our own experiences matter and the same applies to teacher education researchers who also need to develop a powerful

voice and influence in how teacher education programs might be further developed. Our understanding of what we, as teacher educators, are doing is connected to our interactions with student teachers and their concerns and dilemmas. In the same way as student teachers are travelling on a complex journey, teacher educators are doing the same. We encourage student teachers to begin their learning journeys, but we must not forget to join them on that journey, and hence, become reflective practitioners in the complex enterprise of teacher education practice.

7. Implications and future research

What then are the implications for this research on student teachers' complex journey from learners to teachers? What do we learn from it and in what way might the results contribute to that double aim that Bassey (1981) highlighted; to result in generalizations in the form of theories of learning and the knowledge base needed for teaching, and to contribute to a change in the practice of teacher education? Just as teacher education programs must be targeted at student teachers' concerns to translate required knowledge into effective classroom practice, there is also a need for more extensive research on the required knowledge and how it is developed during pre-service teacher education. However, the goal of teacher education is not to "tell" student teachers how to teach, but to educate them to reason soundly about their teaching as well as helping them make explicit their needs and concerns for teaching. Sound reasoning requires both a process of thinking about *what* and *how* they are doing and an adequate base of facts, principles and experiences from which to reason.

Further to this, in order to close the "zipper" between theoretical knowledge (of science as well as pedagogy) and practical knowledge, teacher educators must be able to clearly demonstrate not only that theories, ideas, and research taught in teacher education programs are evident in the practice of teachers, but also *how* the theoretical knowledge is actually linked to practice. To be trustworthy in such a task (i.e., in helping student teachers to close the zipper), teacher educators also need to "enter the school classrooms floor" to teach (Pinnegar, 1995; Russell, 1995) or to study classroom interactions (e.g., like in the studies presented in this thesis) and what is actually happening in a teaching situation.

In order to teach physics for primary science student teachers, it might well be argued that deep physics knowledge itself is not enough. Also, it is reasonable to suggest that university teachers need to know something about the primary school context in which the student teachers will teach in their future professions. Hence, if pre-service teacher education programs are to facilitate the professional development of student teachers, teacher educators must understand the processes by which student teachers grow professionally and the conditions that support and promote such growth. One idea of so doing might be to create arenas for learning about teaching (such as focus groups) for teacher educators to interact with school teachers as well as university teachers from different disciplines (e.g., science and pedagogy).

Another interesting issue raised through this thesis is that of a *pedagogy of teacher education*. It is too often the case that studies (such as this) draw attention to particular aspects of learning, teaching or teacher education but do not link those outcomes to the ways in which the teaching of teacher education is conducted. This thesis highlights the importance of listening to student teachers' personal stories to consider the difficulties that they face within the teaching and learning processes so that they might, as Veenman (1984) suggested, begin to identify, analyze and address their teaching concerns. As such, one of the main results of this thesis concerns the need for, and the practice of, conscious reflection on learning and teaching practices; for student teachers as well as teacher educators. Thus, action research projects in teacher education, where teacher educators and student teachers document and further explore their teaching and learning processes (e.g., through stimulated recall sessions) might be one possibility to work with conscious reflection in teacher education.

Another implication of this thesis concerns the usefulness of the PCK framework. The concept, as it was illustrated by Bishop and Denley (2007) as a spinning-top, could well be used in teacher education to design pedagogical strategies as well as an analytic lens to study [the development of] “successful teaching”. The PCK framework can also guide further research and curriculum development work in the area of teacher education in order to integrate different knowledge such as subject matter, pedagogy and knowledge of the context. Hence the PCK framework might help us to identify not only *what* is important but also *why* and *how* aspects of teacher knowledge might become important to promote pupils’ learning. However, it might be suggested that what is required is a shift in focus in science teacher education whereby science teacher education curricula could be built around PCK, as an essential tenet in leading to improvements in student teachers´ problems with the interface between SMK and PCK. Therefore, further research is crucial on how student teachers experience the practice of teaching science, how to interpret those experiences, what constitutes teacher knowledge and in what way that knowledge impacts pupils’ learning. As such, it is important that teacher educators, in developing their pedagogy of teacher education, seek to find ways of incorporating student teachers’ needs and concerns into their teaching about teaching in ways that are sympathetic to their context but that explicitly challenge student teachers’ learning about teaching in ways that are based on their own experiences of teaching. In so doing, teacher educators’ pedagogical content knowledge and reflective skills are important.

To end, what is the next stop in my own (as a researcher) learning journey and where do I go from here? One of the tracks that I have already started to travel along is to further investigate teacher educators’ teaching and *their* learning journeys in order to develop pedagogical content knowledge. Further to this there is a need to look closer to the ontological perspectives of the discourse of university science and how it is related (or not) to the discourse of school science.

Another missing link in this thesis is the relation between teaching and the pupils’ learning and experiences of the science teaching. I began this research five years ago with an intention to study primary pupils’ communication and learning in physics through physics teaching and practical experiments in the classroom (Nilsson, 2004, 2005). However, as a problem became evident to me when I observed what happened to primary school teachers who normally did not teach physics in primary schools, my research interest shifted from only studying pupils' learning to studying student teachers' learning to teach in interaction with the pupils. Now as I conclude the work on this thesis, one idea might be to explore pupils' ideas of science teaching and learning (e.g. what critical aspects within their teacher's teaching do pupils consider as important for their learning?)

In 1986 Shulman noted that teacher education research was overlooking the central role of content and subject matter, a phenomenon he called the "missing paradigm":

"The missing paradigm refers to a blind spot with respect to content that now characterizes most research on teaching and, as a consequence, most of our state-level programs of teacher evaluation and teacher certification….What we miss are questions about the *content* of the lessons taught, the questions asked, and the explanations offered." (Shulman, 1986, p. 7-8)

Now, more than 20 years later, as the policy makers (in Sweden) hold very strong beliefs on teachers' subject matter knowledge, we must be careful that we do not contribute to new "missing paradigms" (e.g., pupils' experiences of their learning of science, or teacher educators' pedagogical content knowledge). Therefore, for future research and for my own continuing journey, I will not only continue together with student teachers but I will also invite university teachers and pupils into this lifelong learning journey.

8. References

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